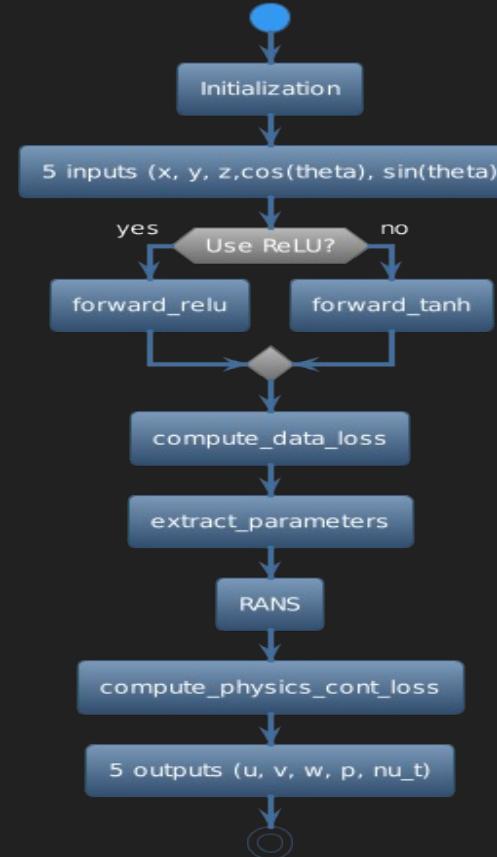
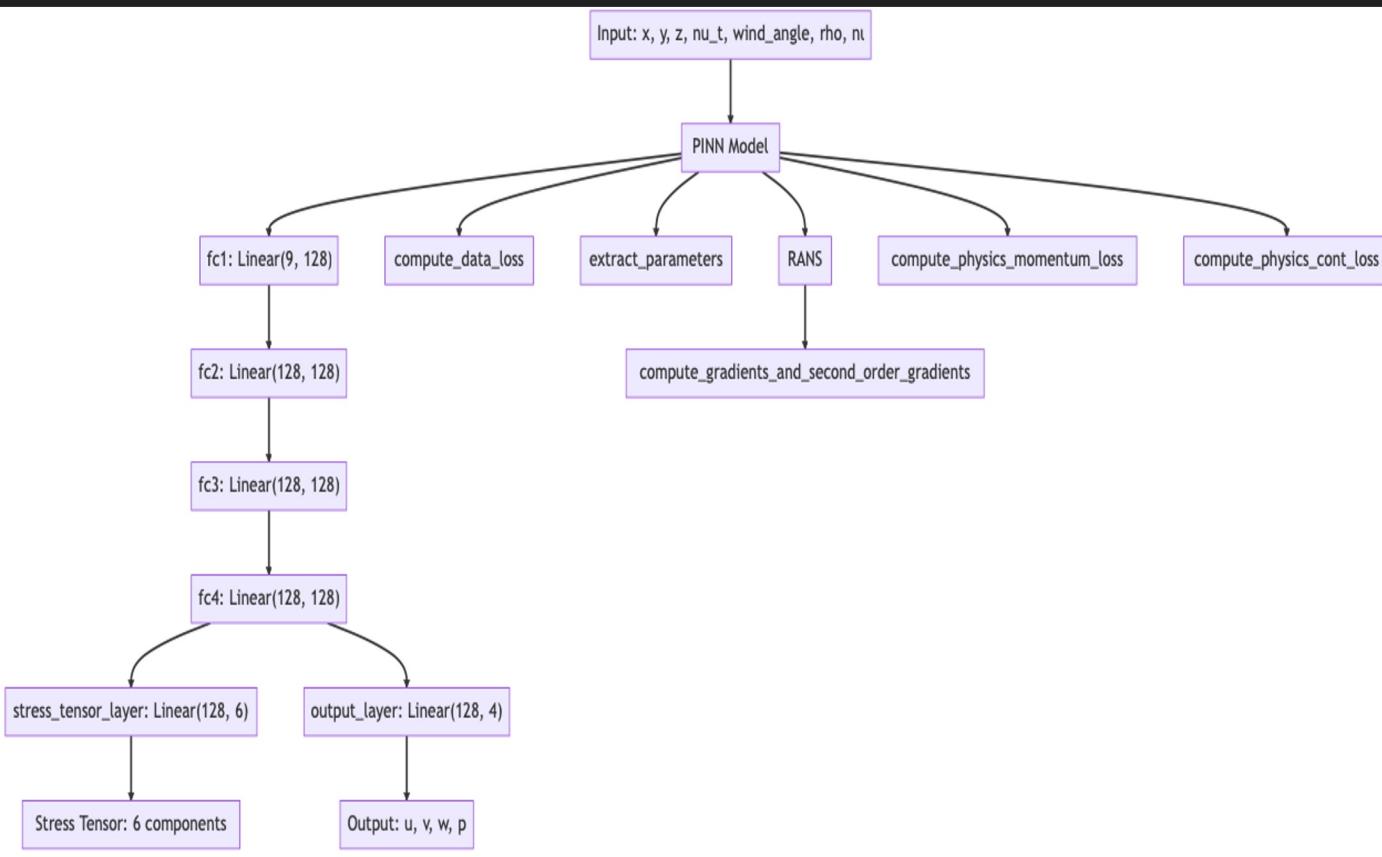


# PM003 – 30\* October 2022

## Update on PINNs

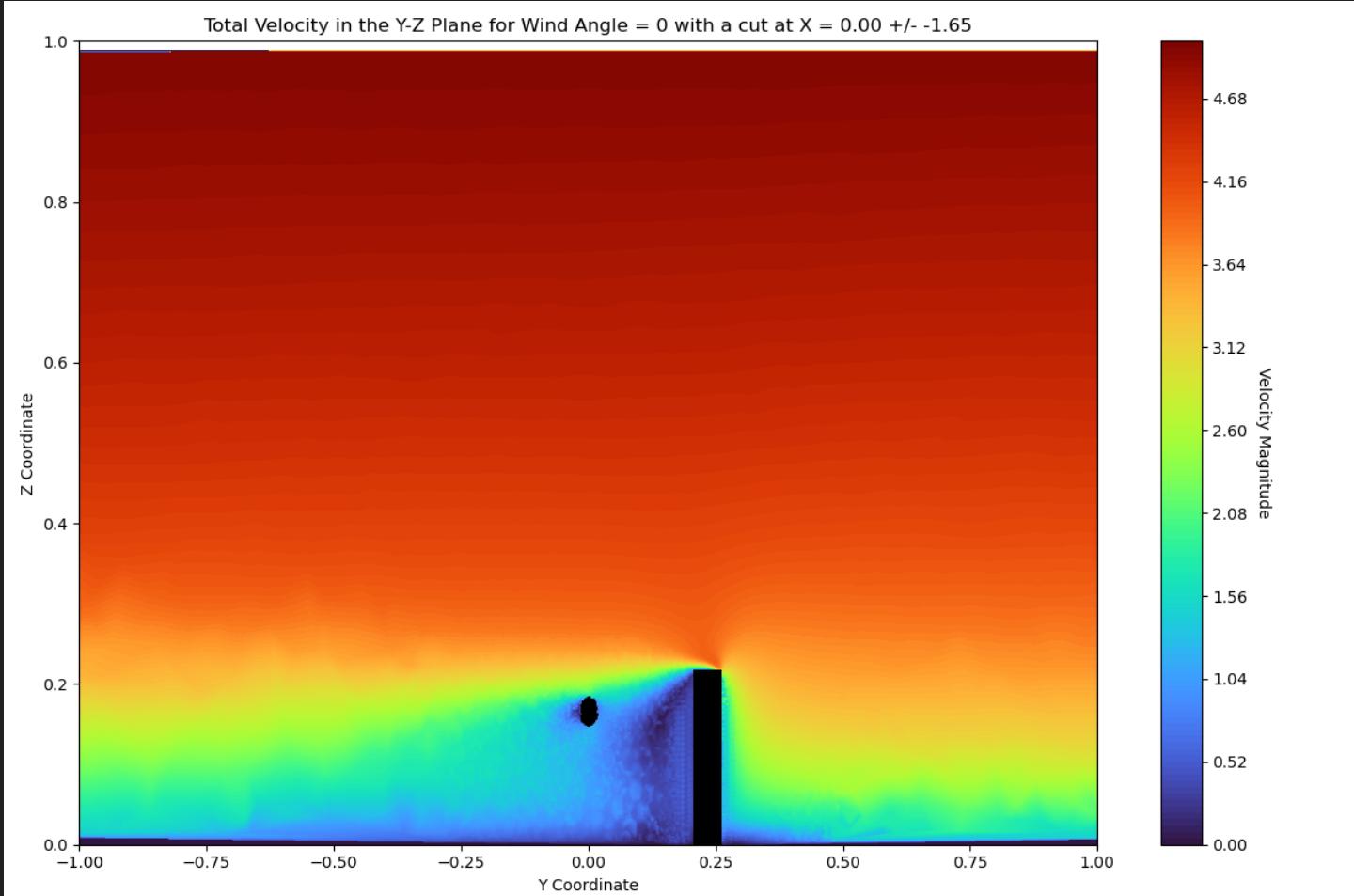
Application to Urban Wind Field Dispersion Studies

# Neural Network Architecture – Previous vs Updated

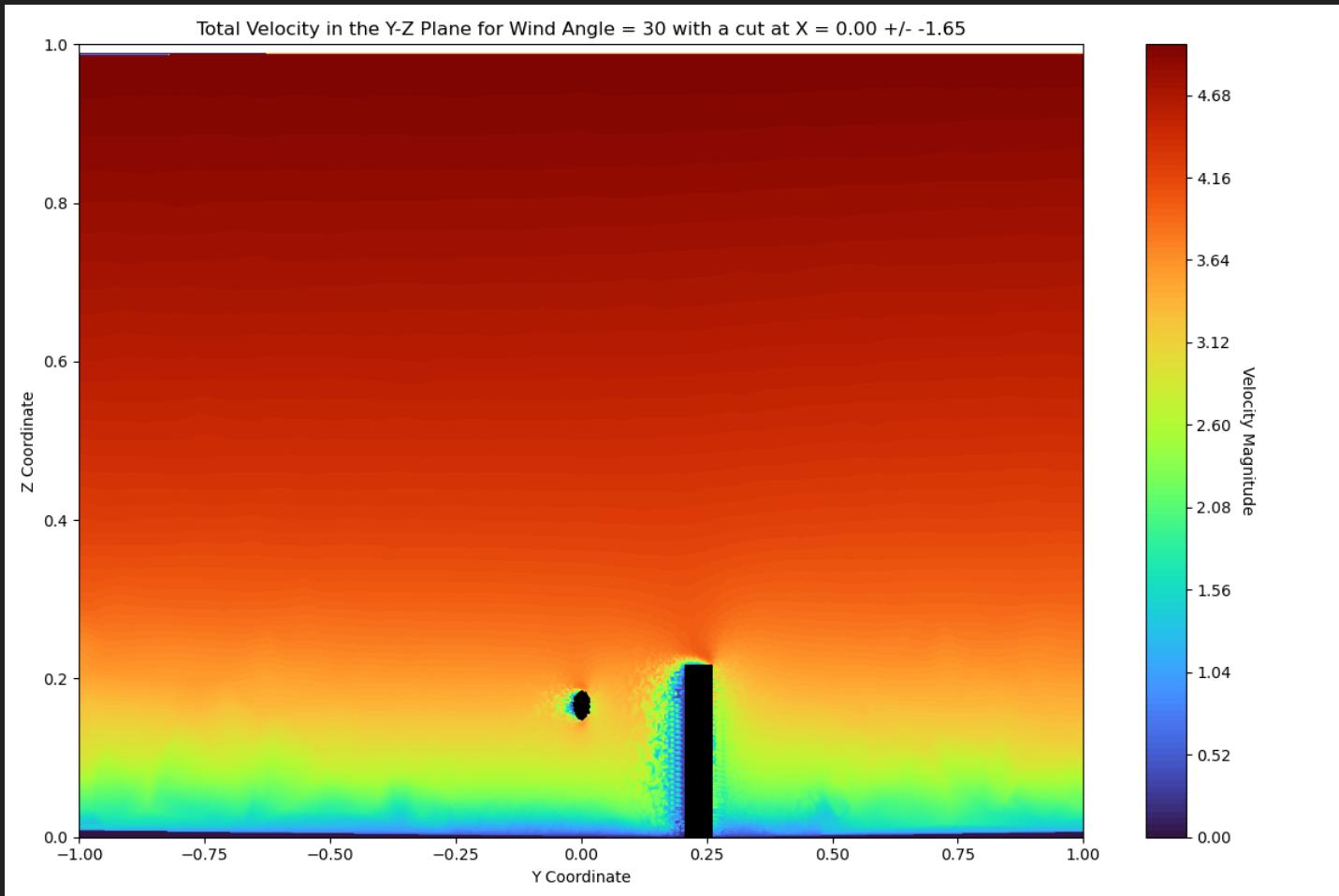


# Pure Data Plots

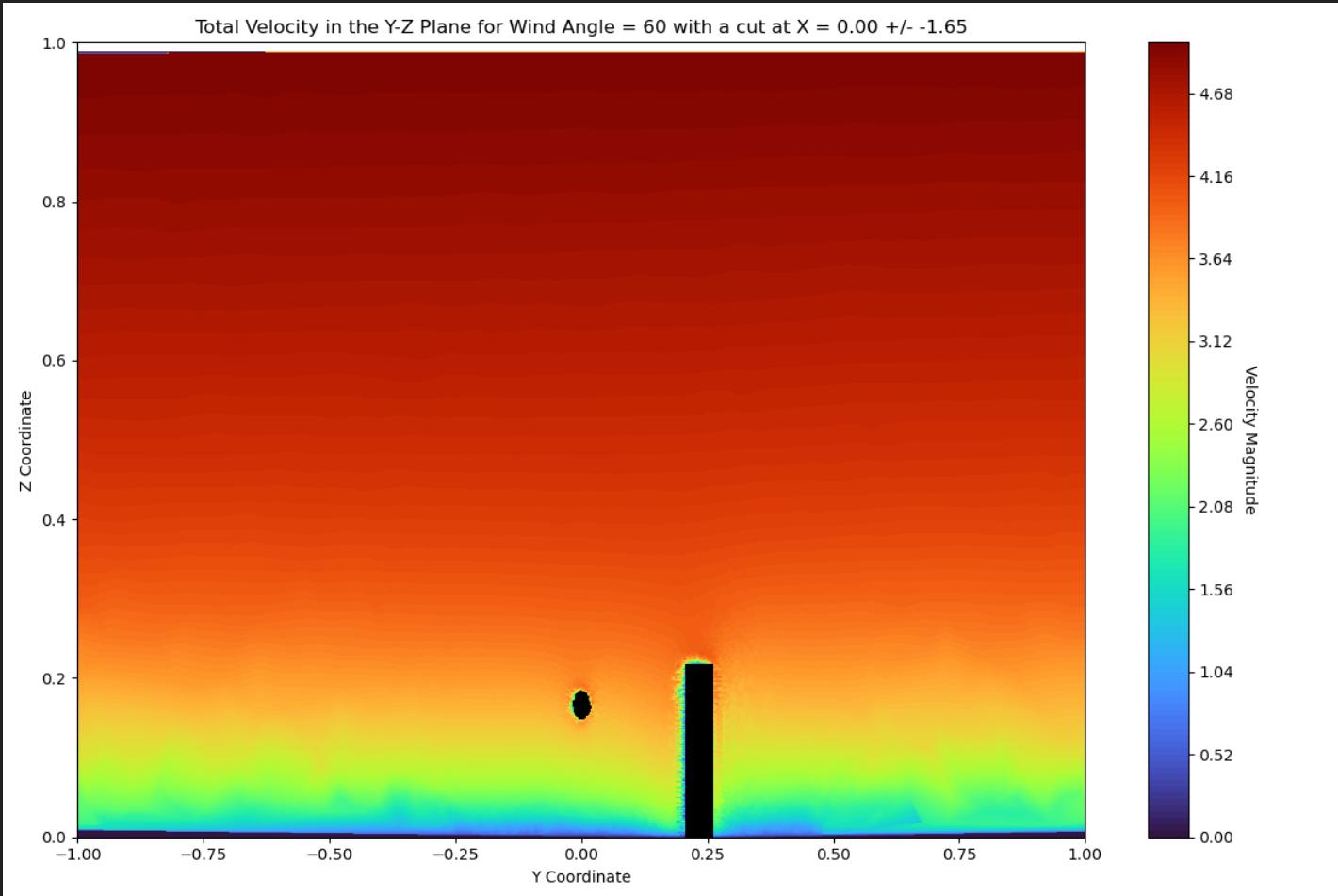
# Data Plots – wind angle = 0



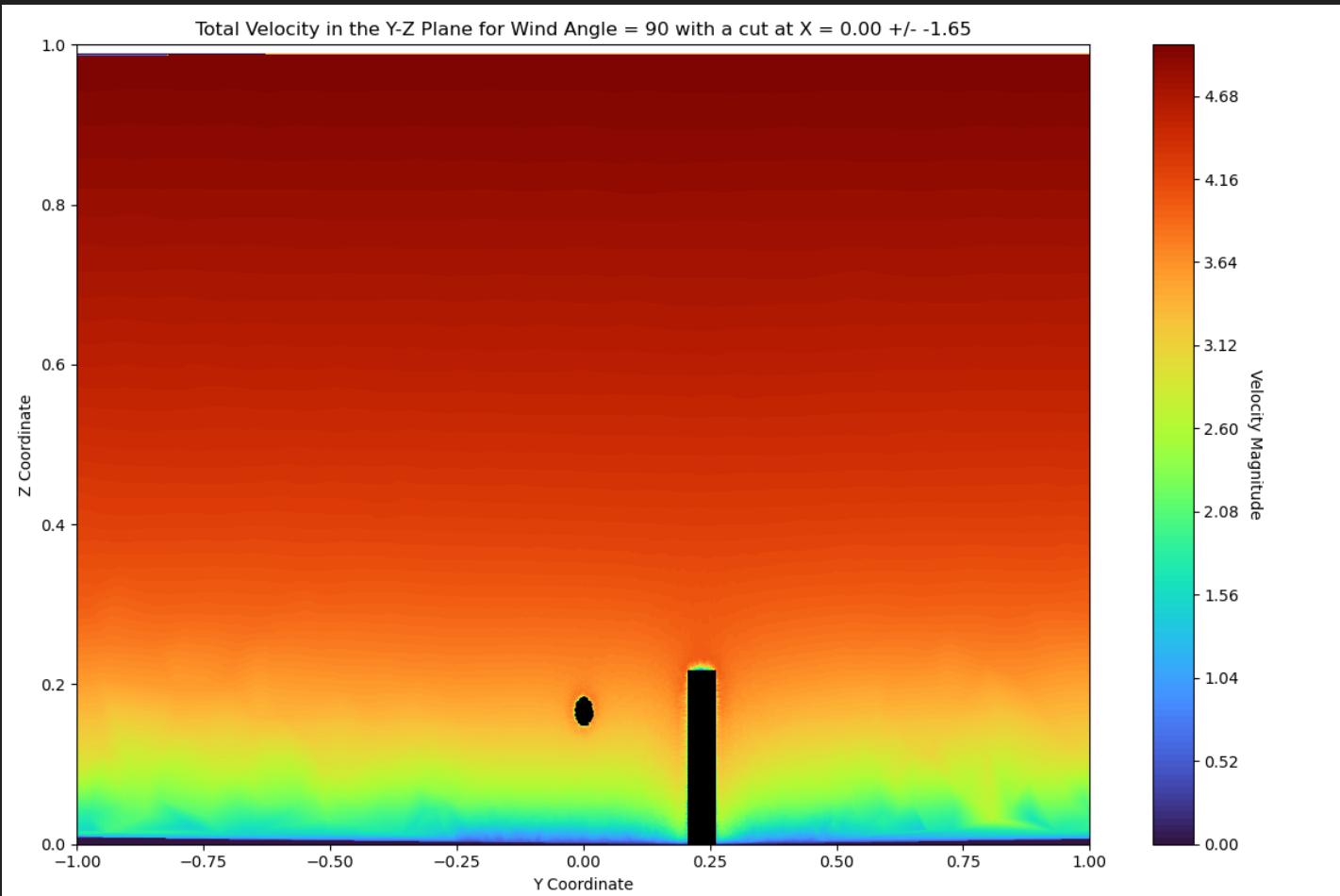
# Data Plots – wind angle = 30



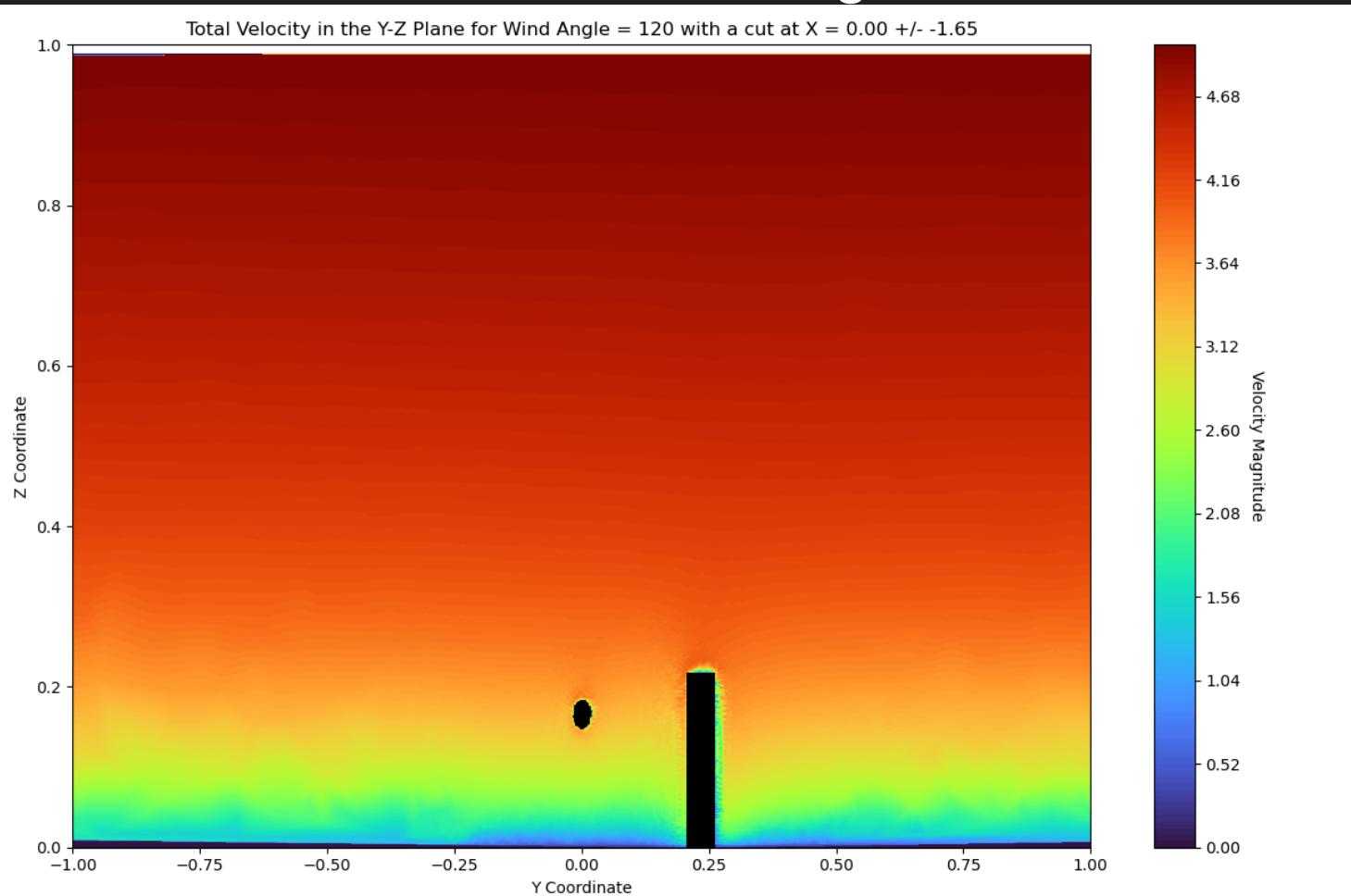
# Data Plots – wind angle = 60



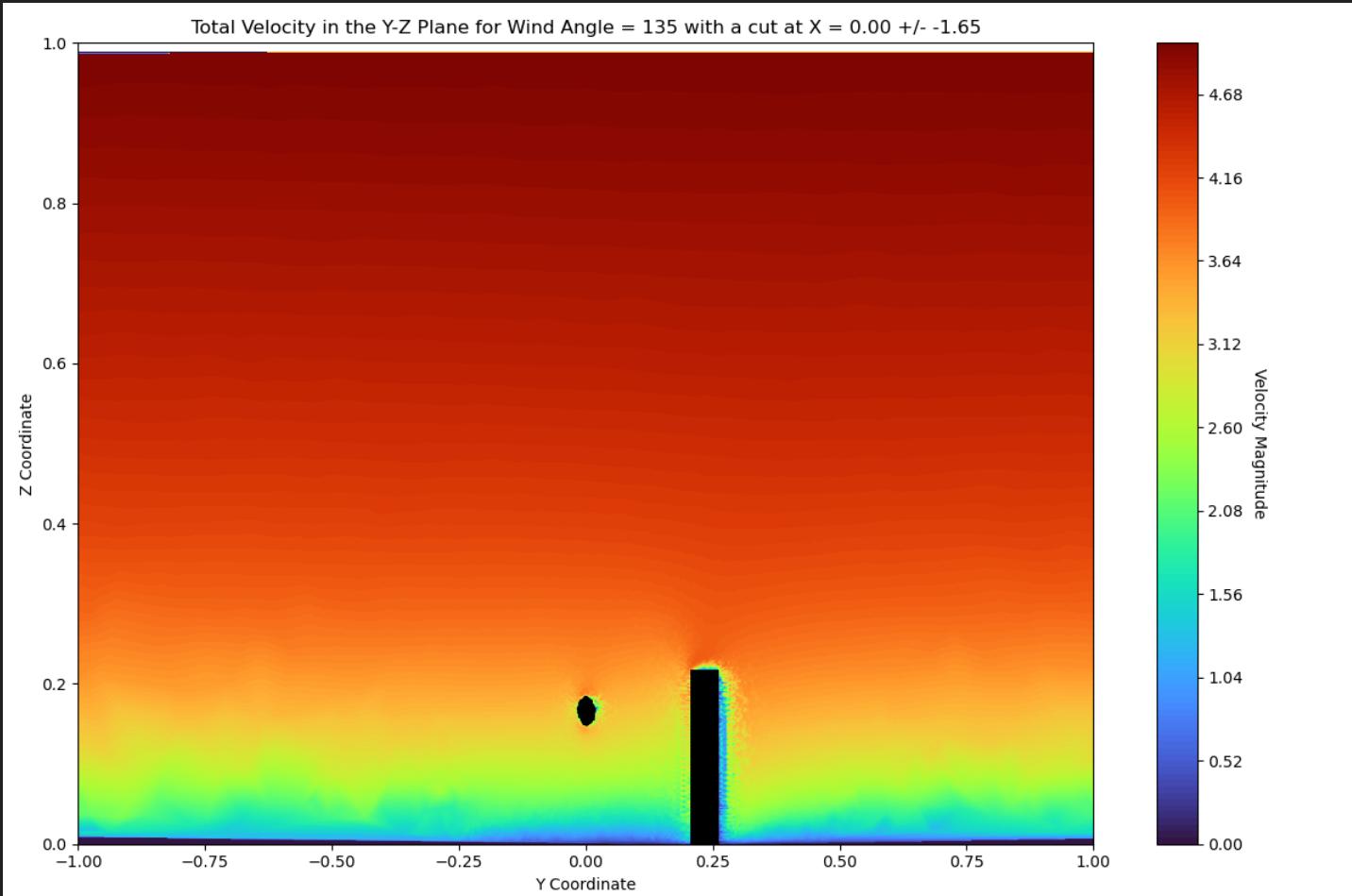
# Data Plots – wind angle = 90



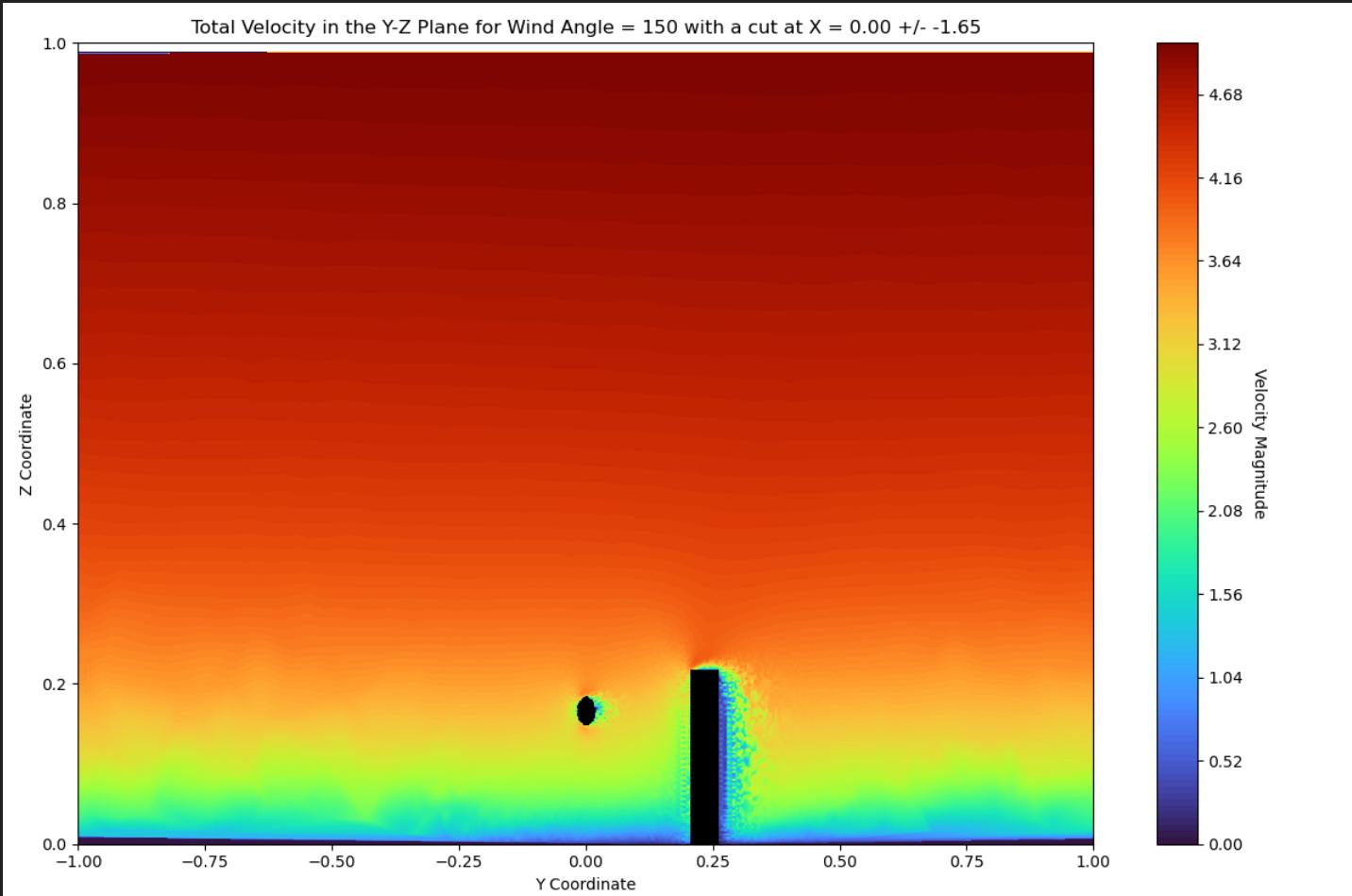
# Data Plots – wind angle = 120



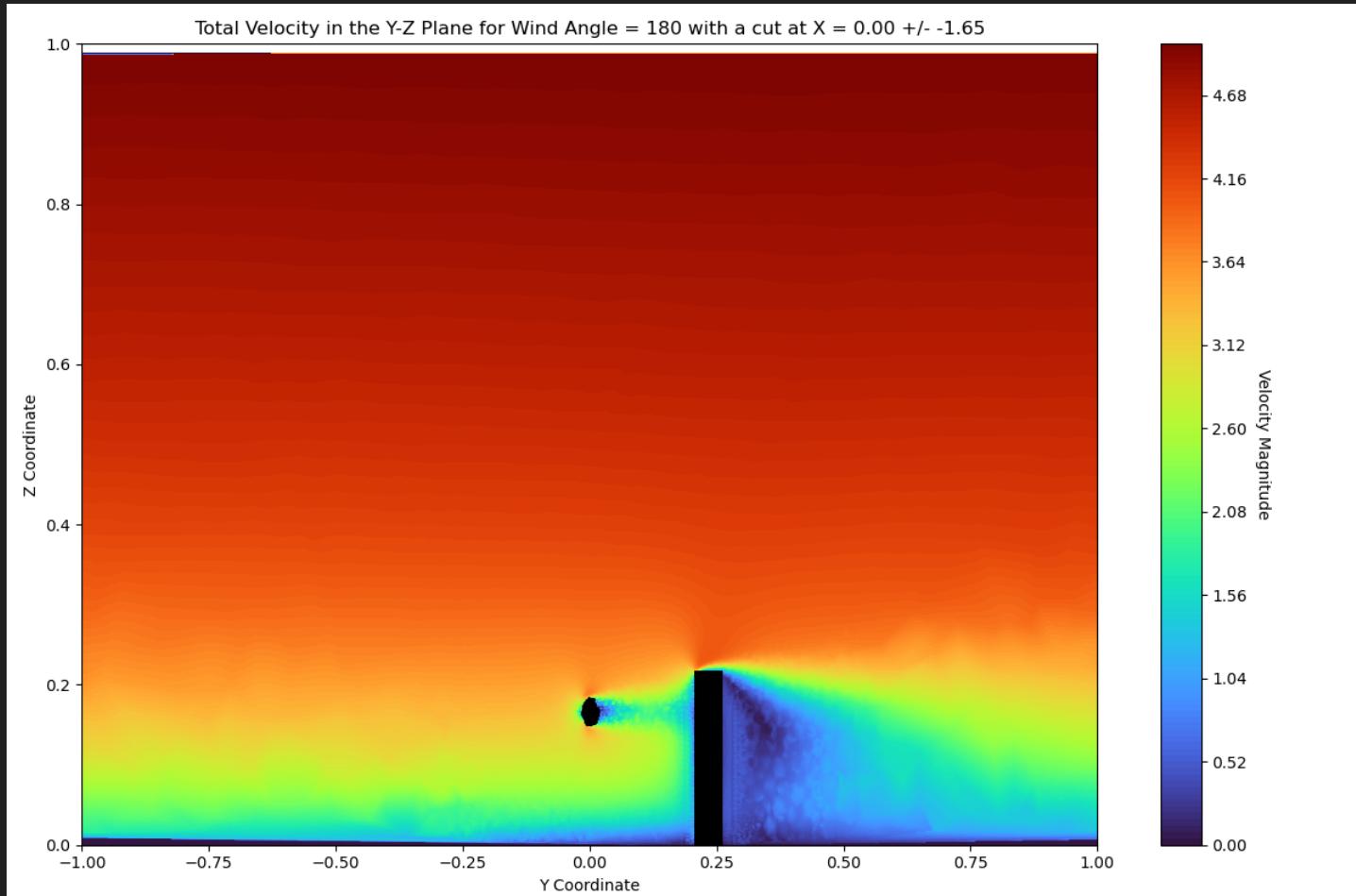
# Data Plots – wind angle = 135



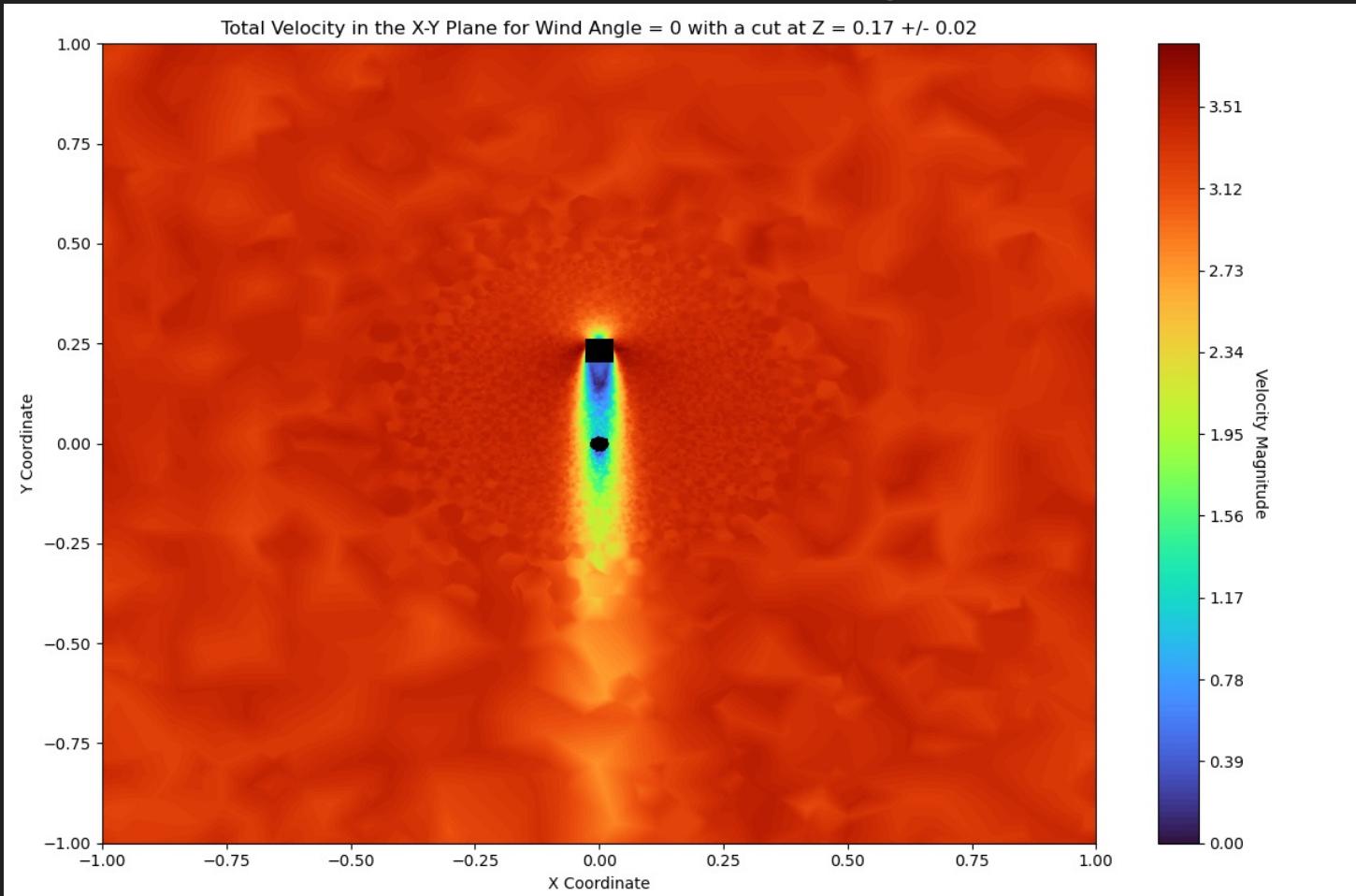
# Data Plots – wind angle = 150



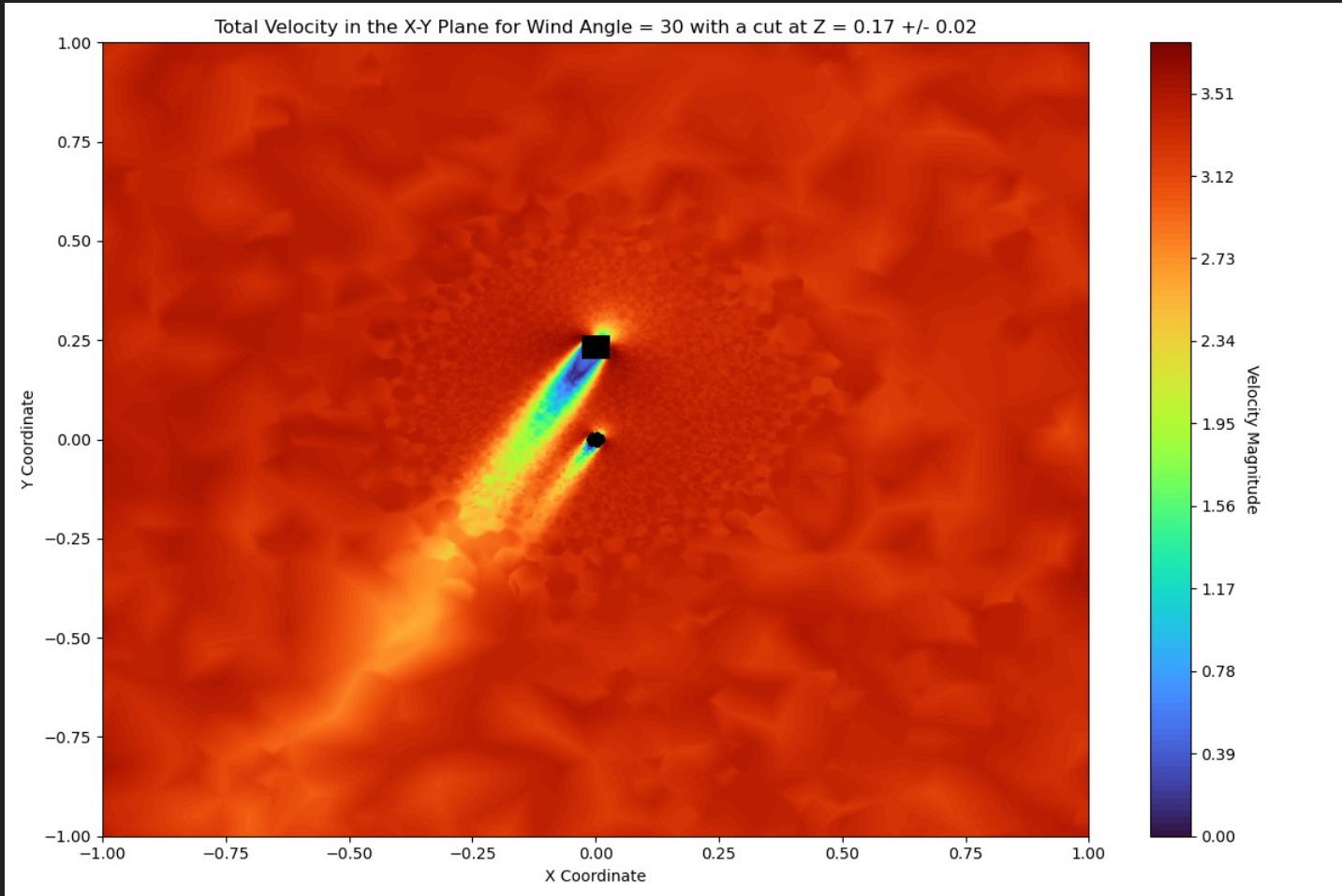
# Data Plots – wind angle = 180



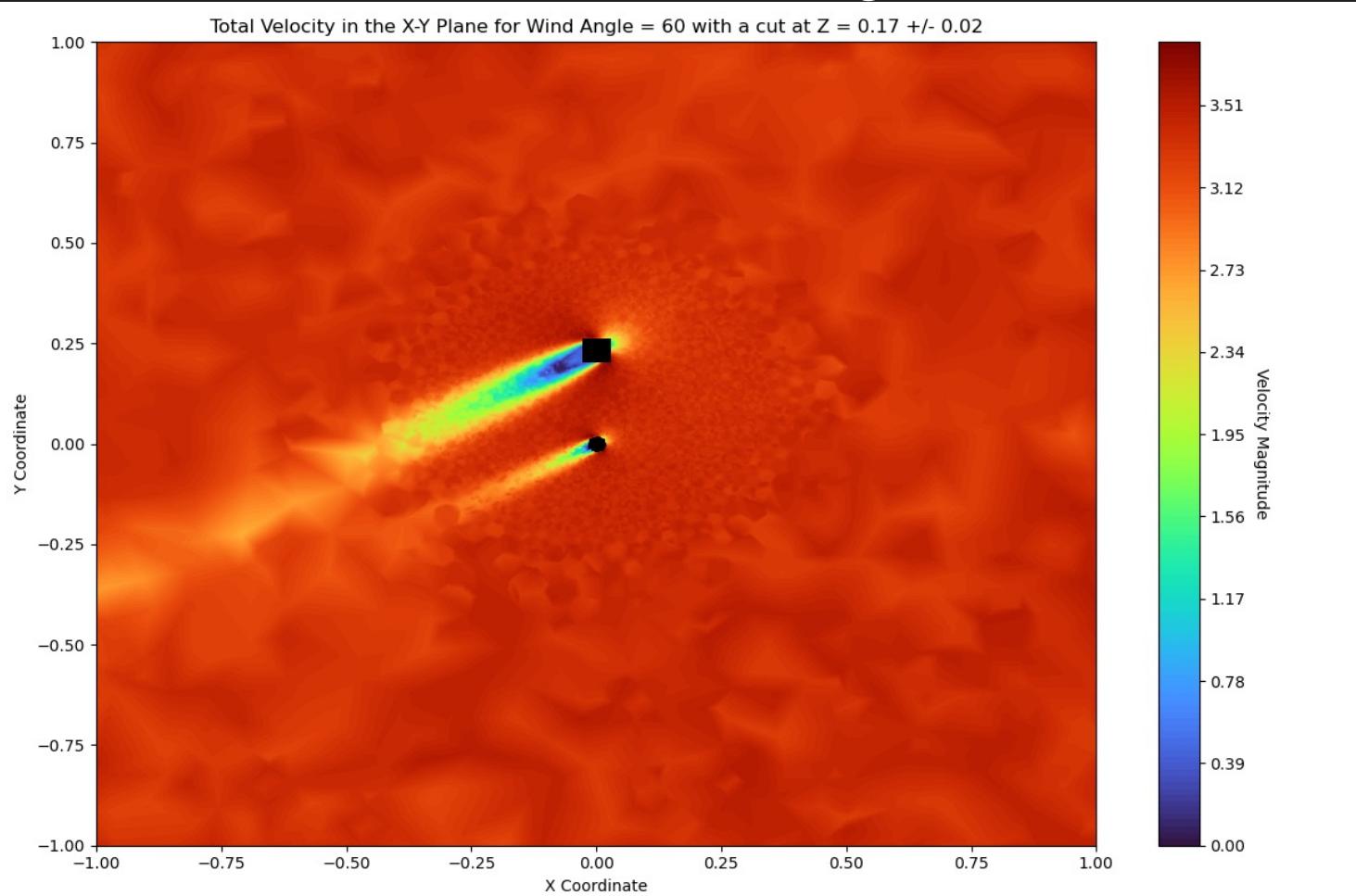
# Data Plots – wind angle = 0



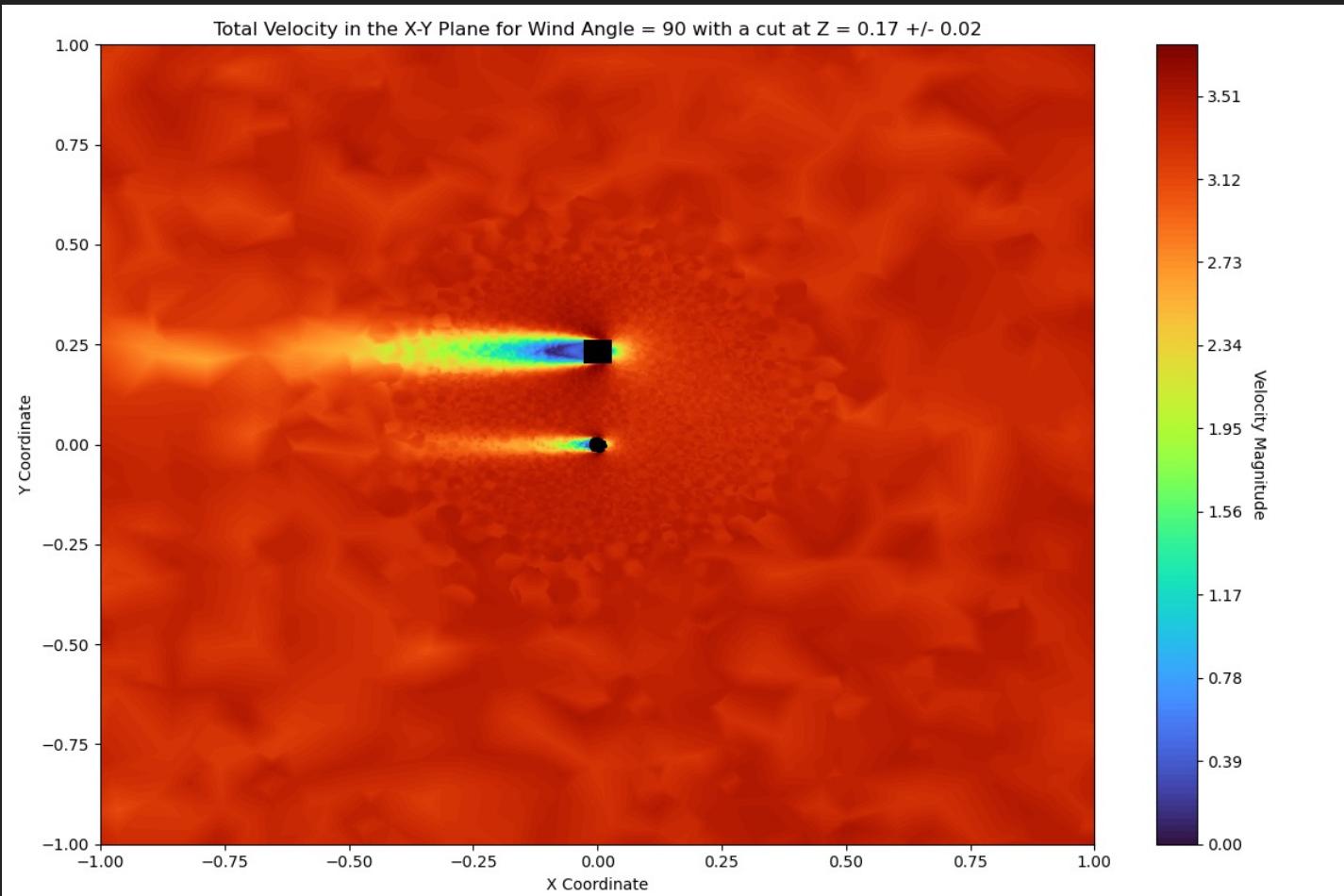
# Data Plots – wind angle = 30



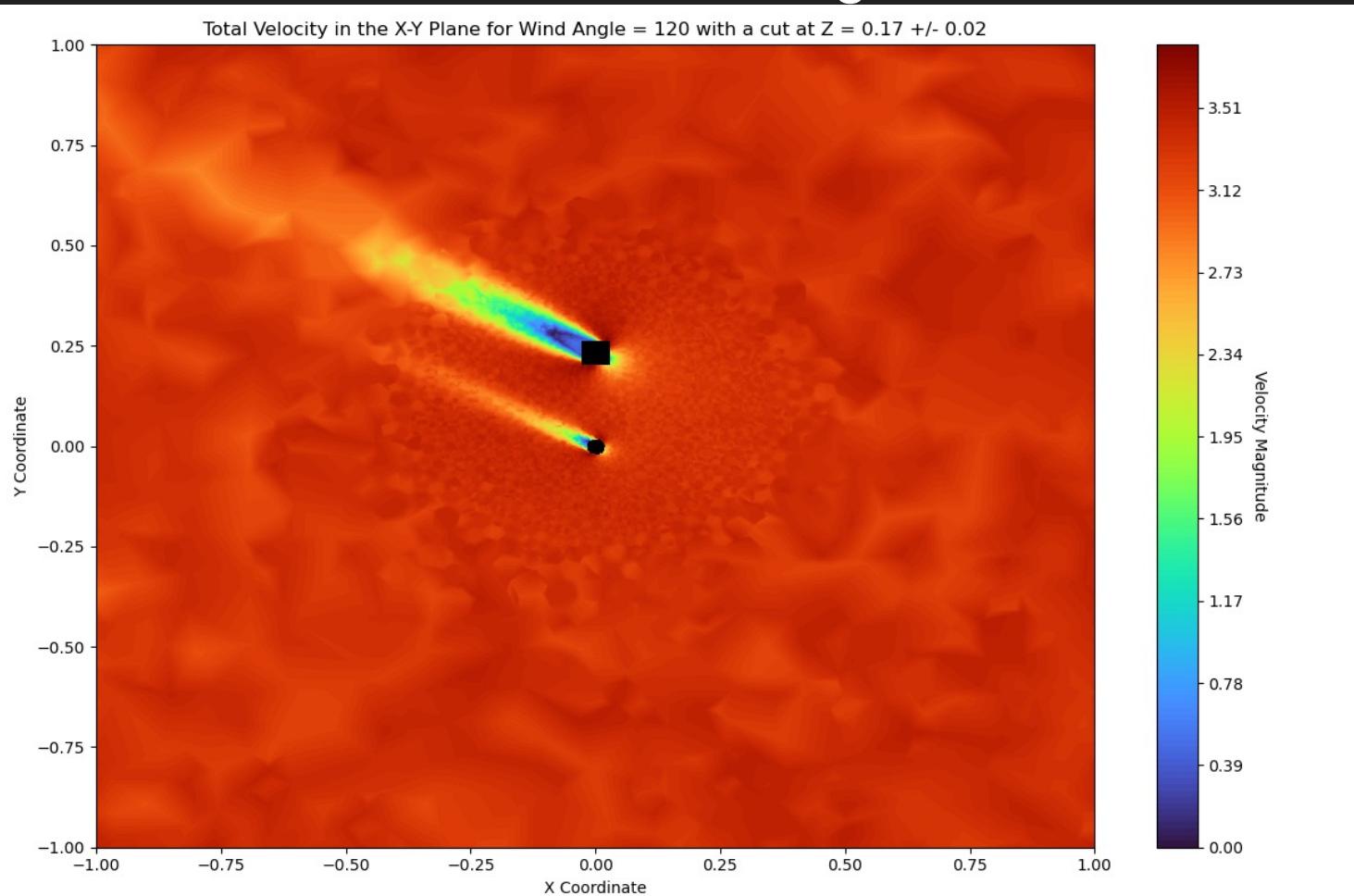
# Data Plots – wind angle = 60



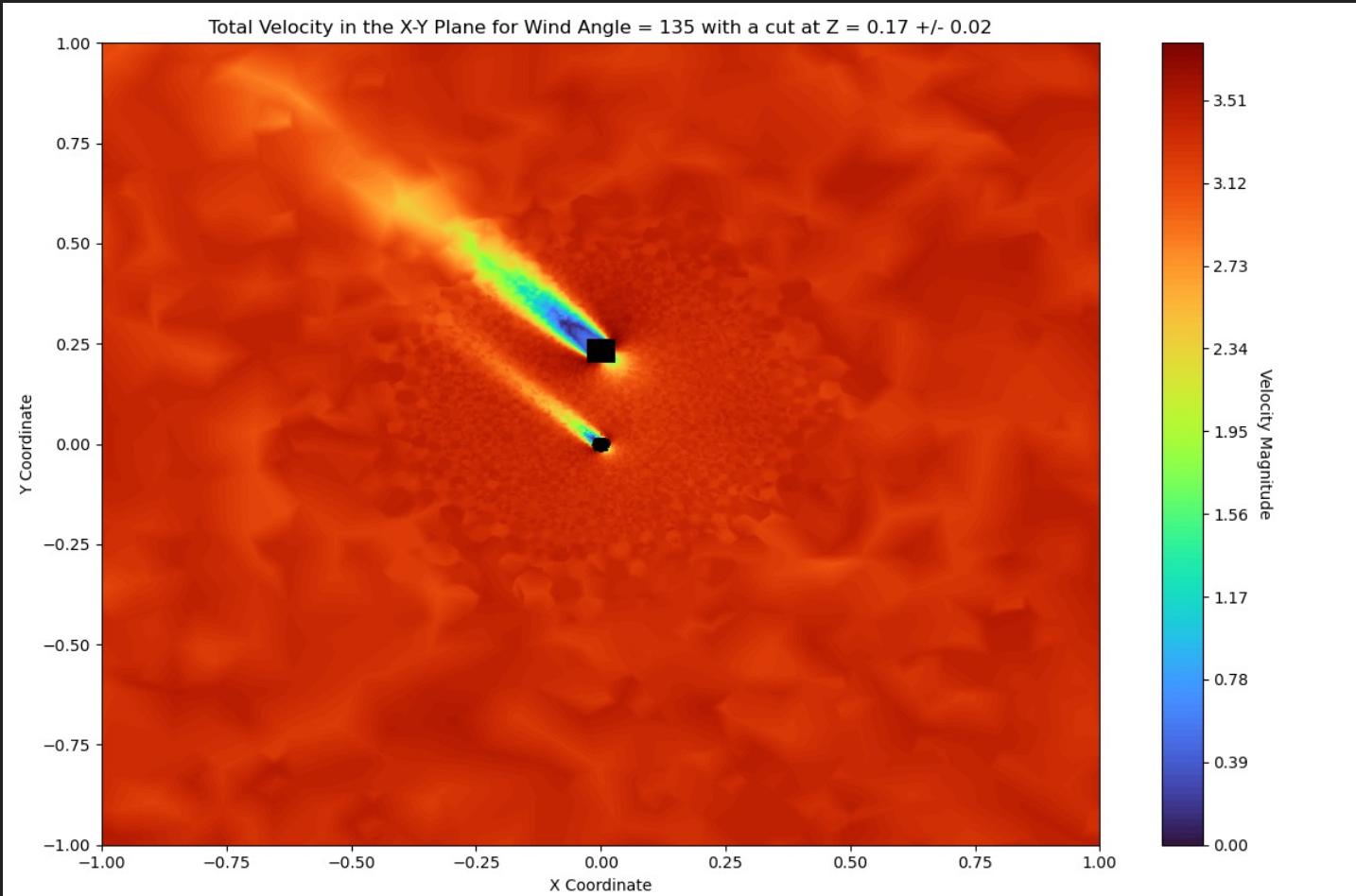
# Data Plots – wind angle = 90



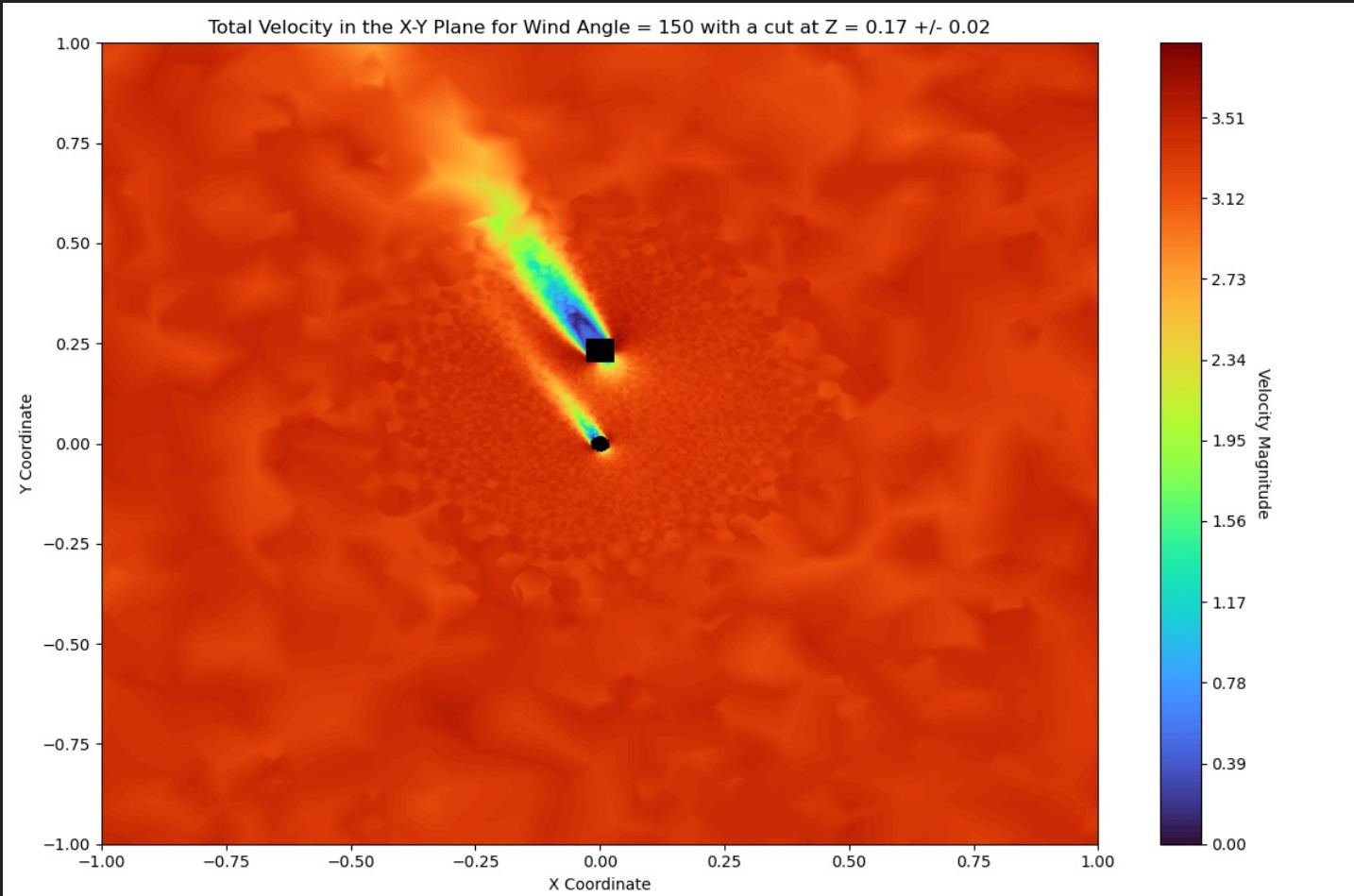
# Data Plots – wind angle = 120



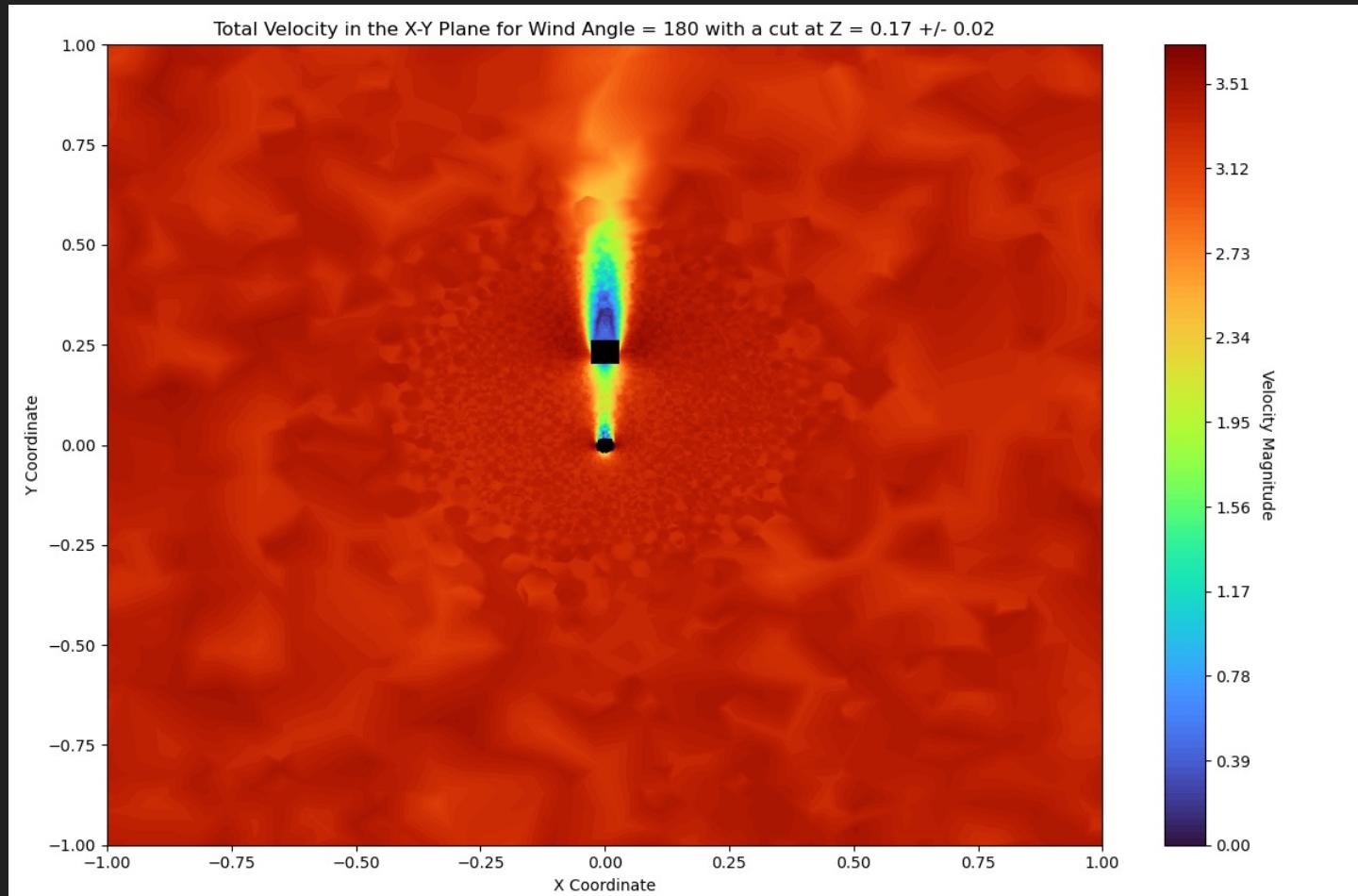
# Data Plots – wind angle = 135



# Data Plots – wind angle = 150



# Data Plots – wind angle = 180



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

Threshold = 1E-5 (9120 Epochs, so far...),  
GPU Laptop

Scripts v1 - TESTING

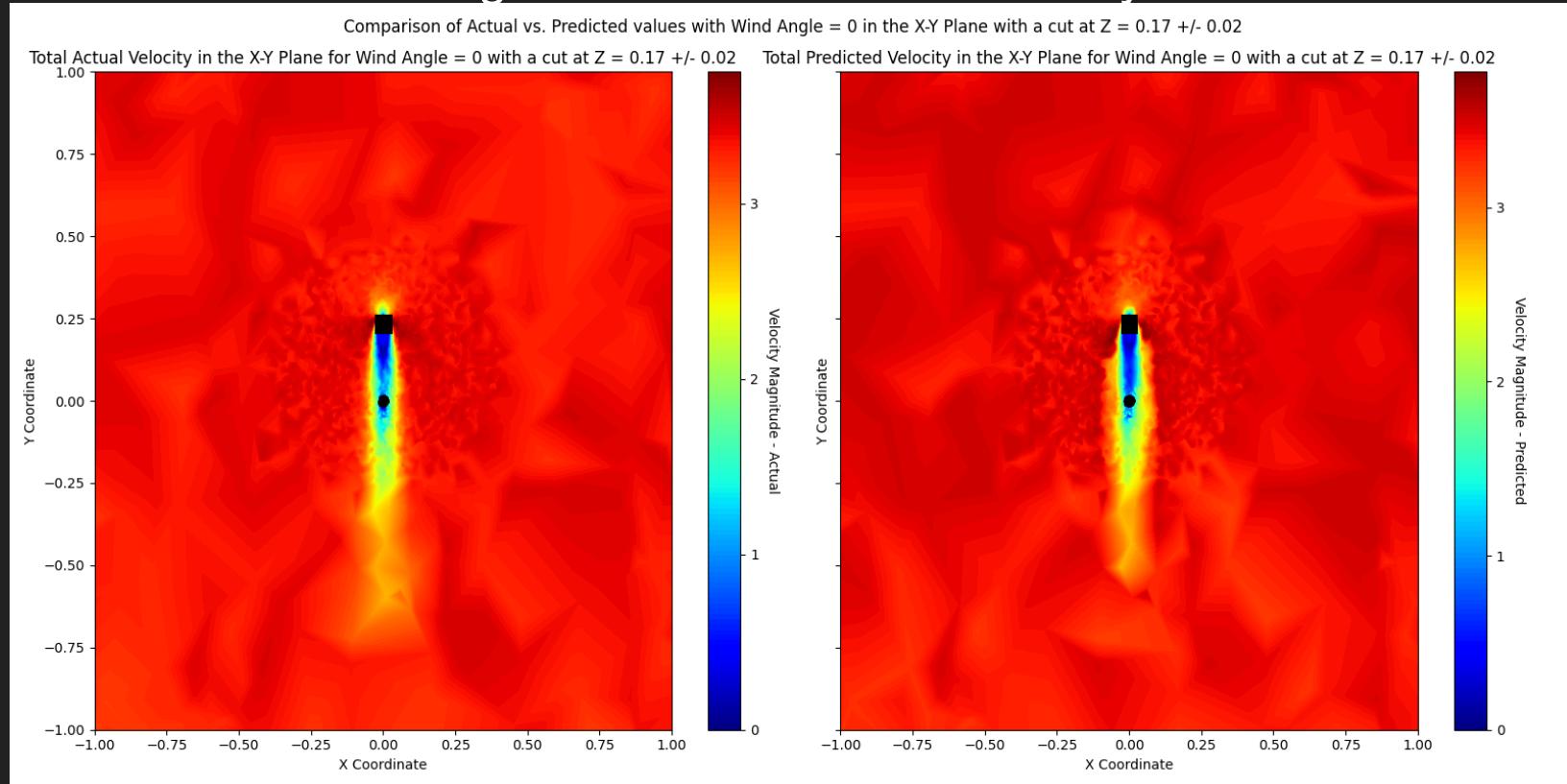
Progress so far - Data Loss + Cont Loss (Adam Optimizer)  
Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop  
Testing Results - Metrics

Variable	MSE	RMSE	MAE	R2
Pressure	0.03058529	0.1748865	0.08485891	0.99351423
Velocity:0	0.01834383	0.13543941	0.06264316	0.99091249
Velocity:1	0.03576996	0.18912948	0.09784344	0.99567361
Velocity:2	0.00020081	0.0141709	0.00805722	0.99350792

# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

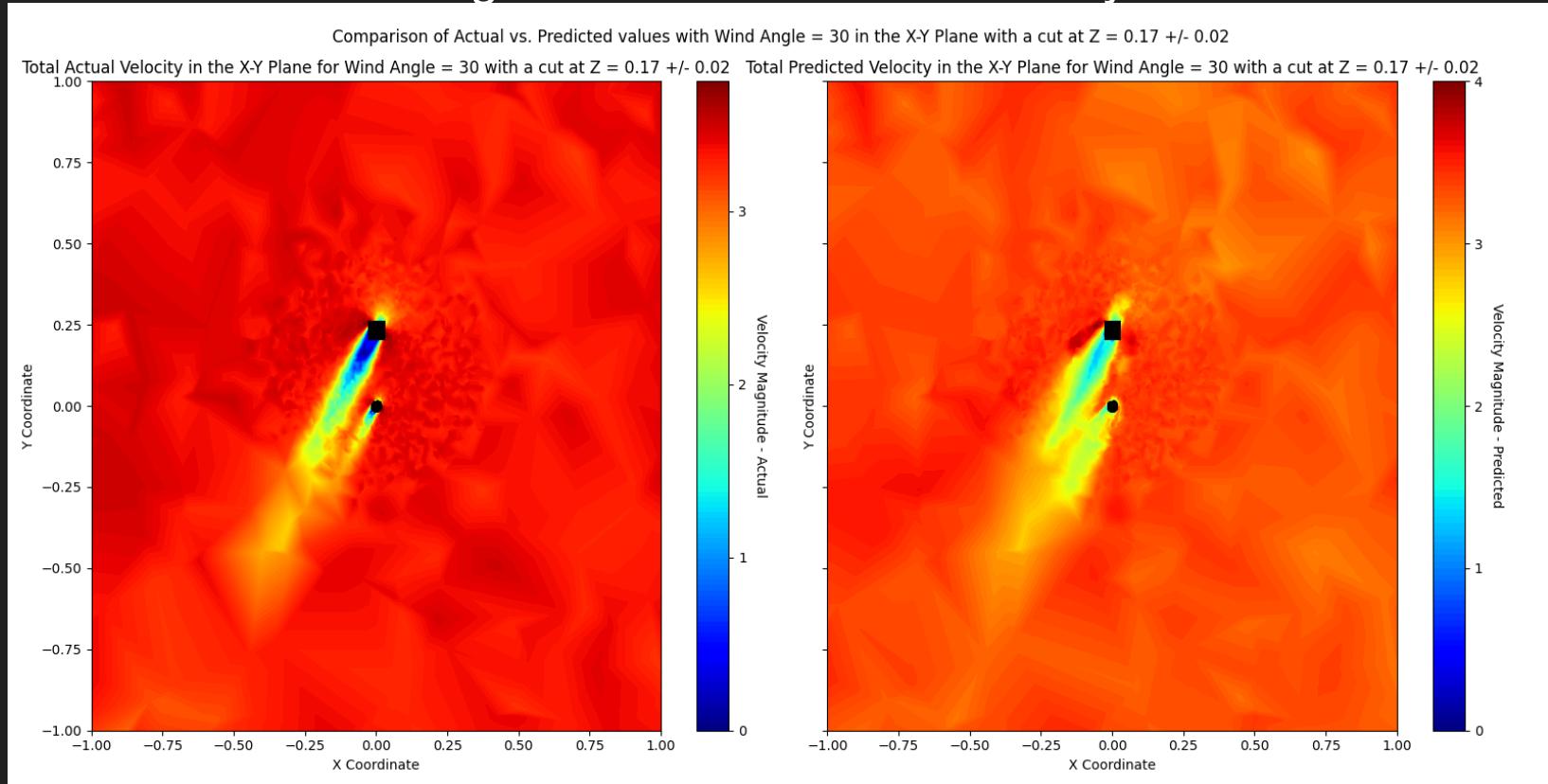
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

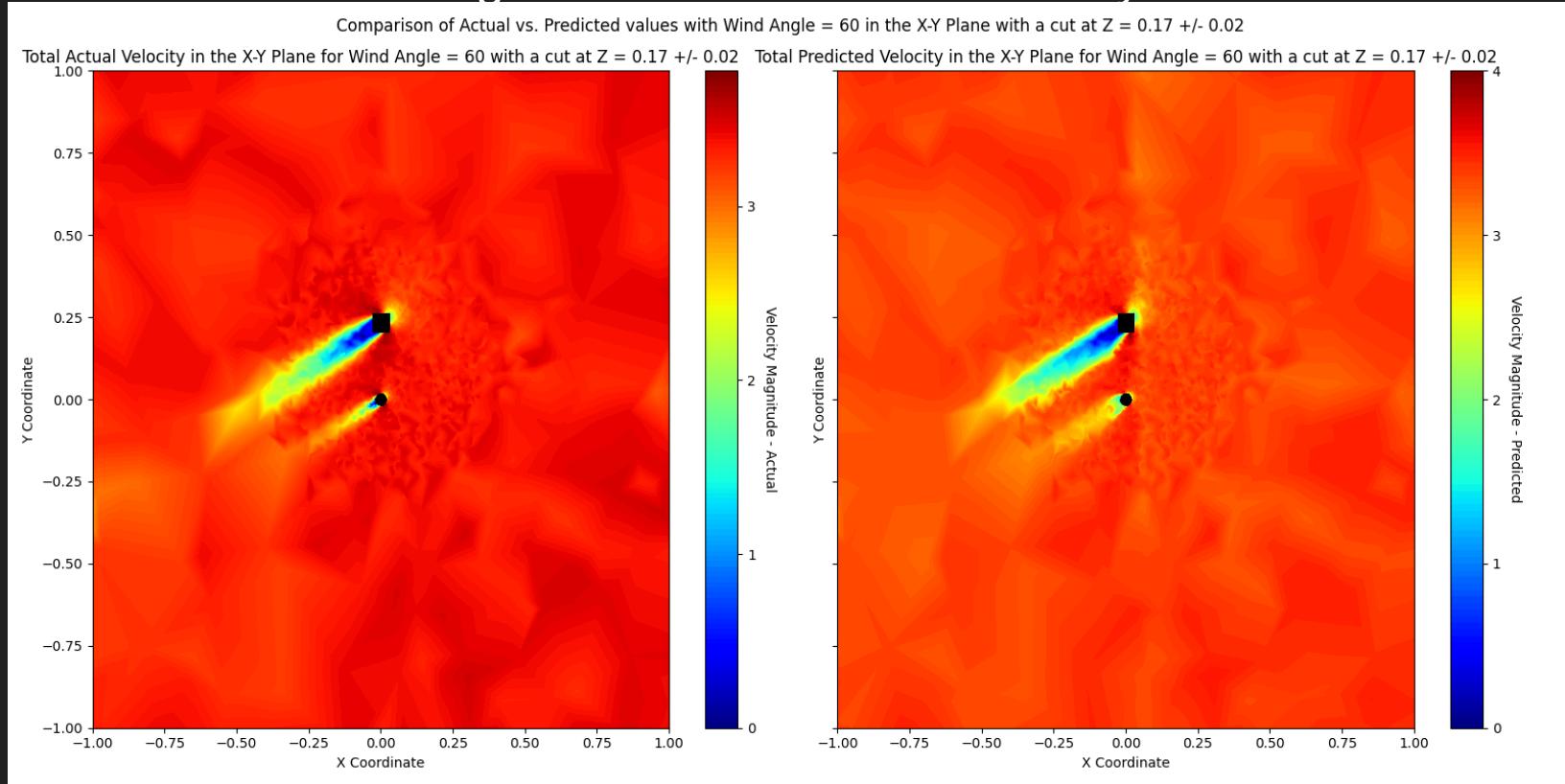
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

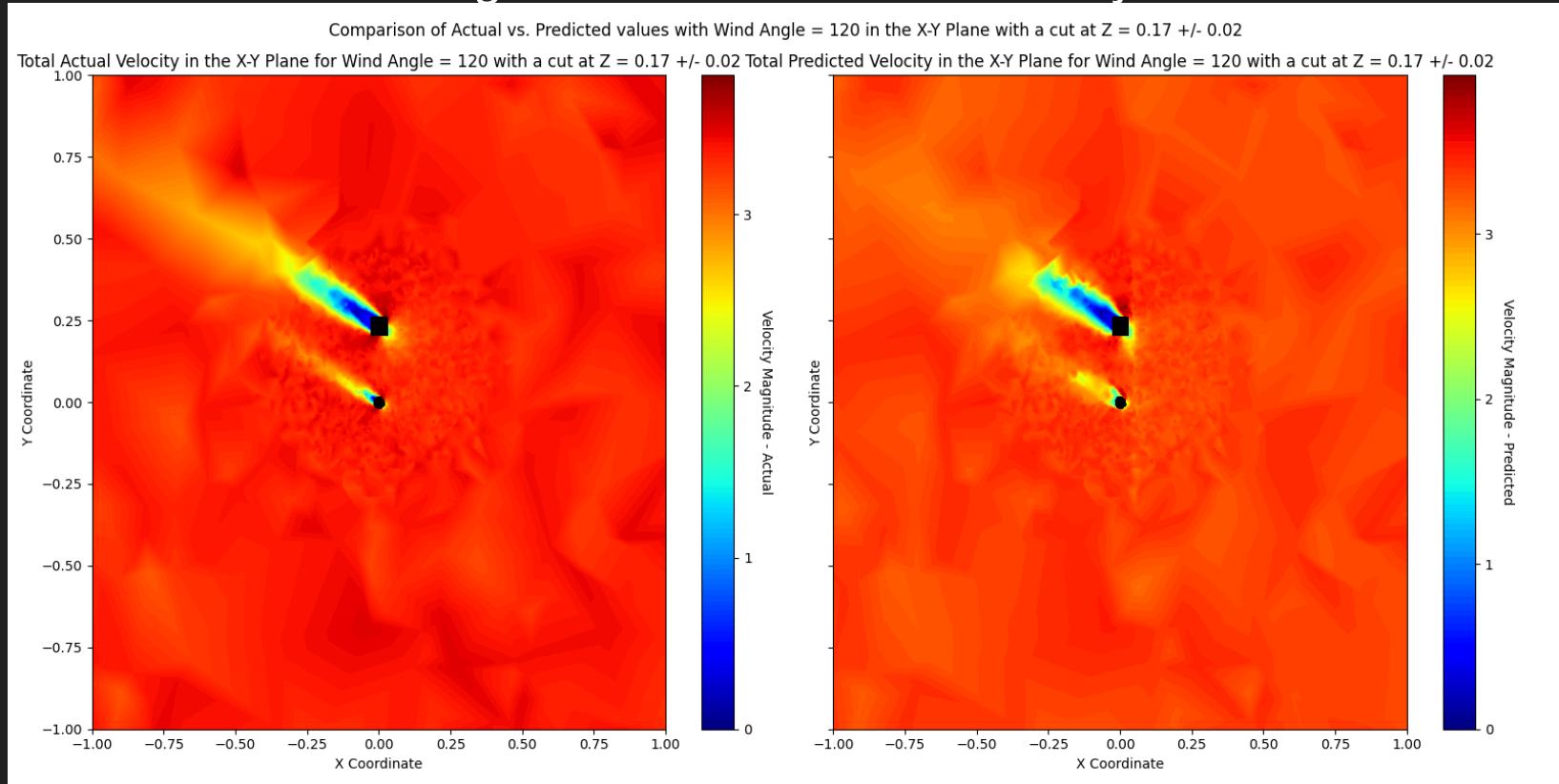
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

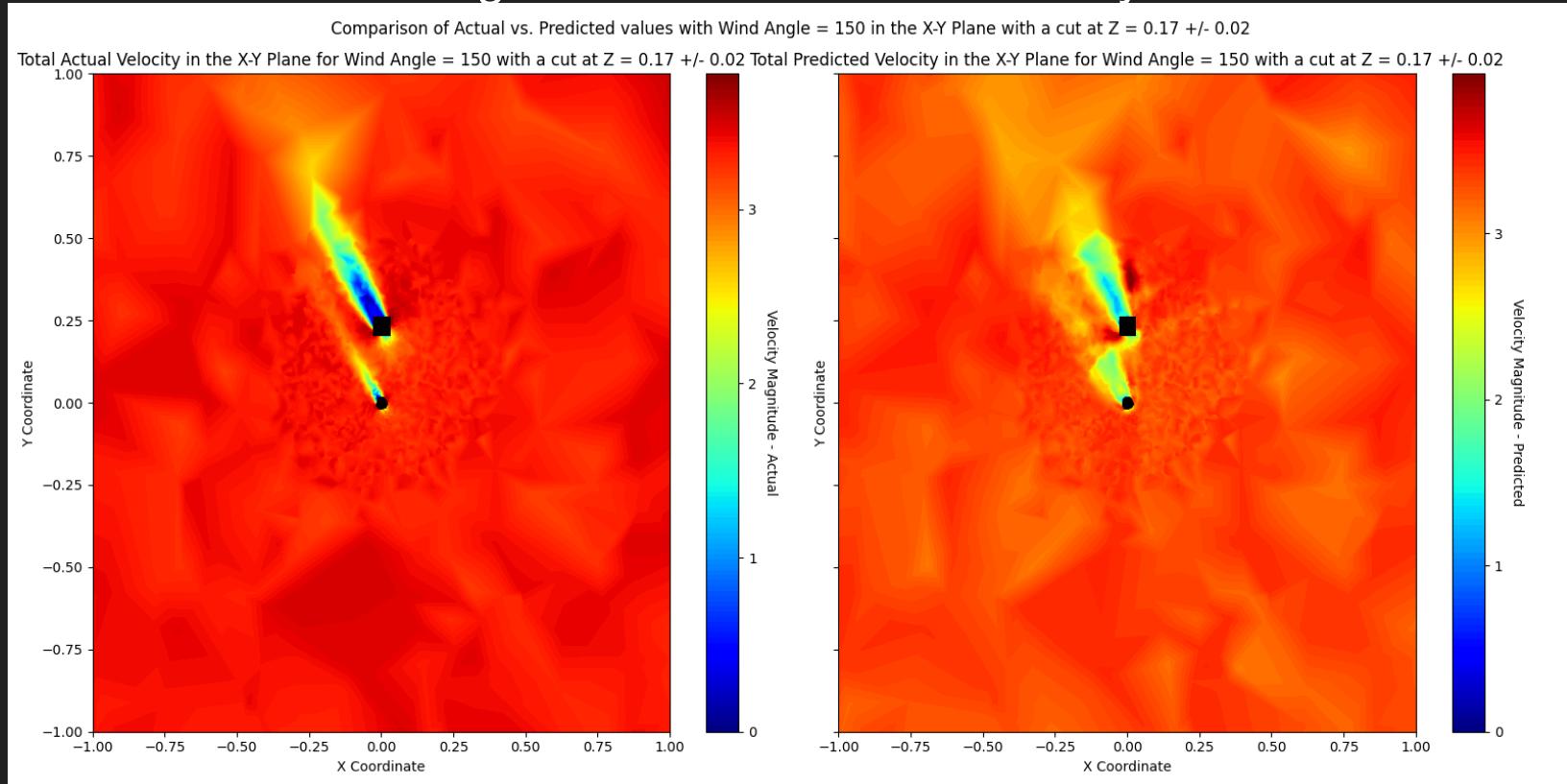
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

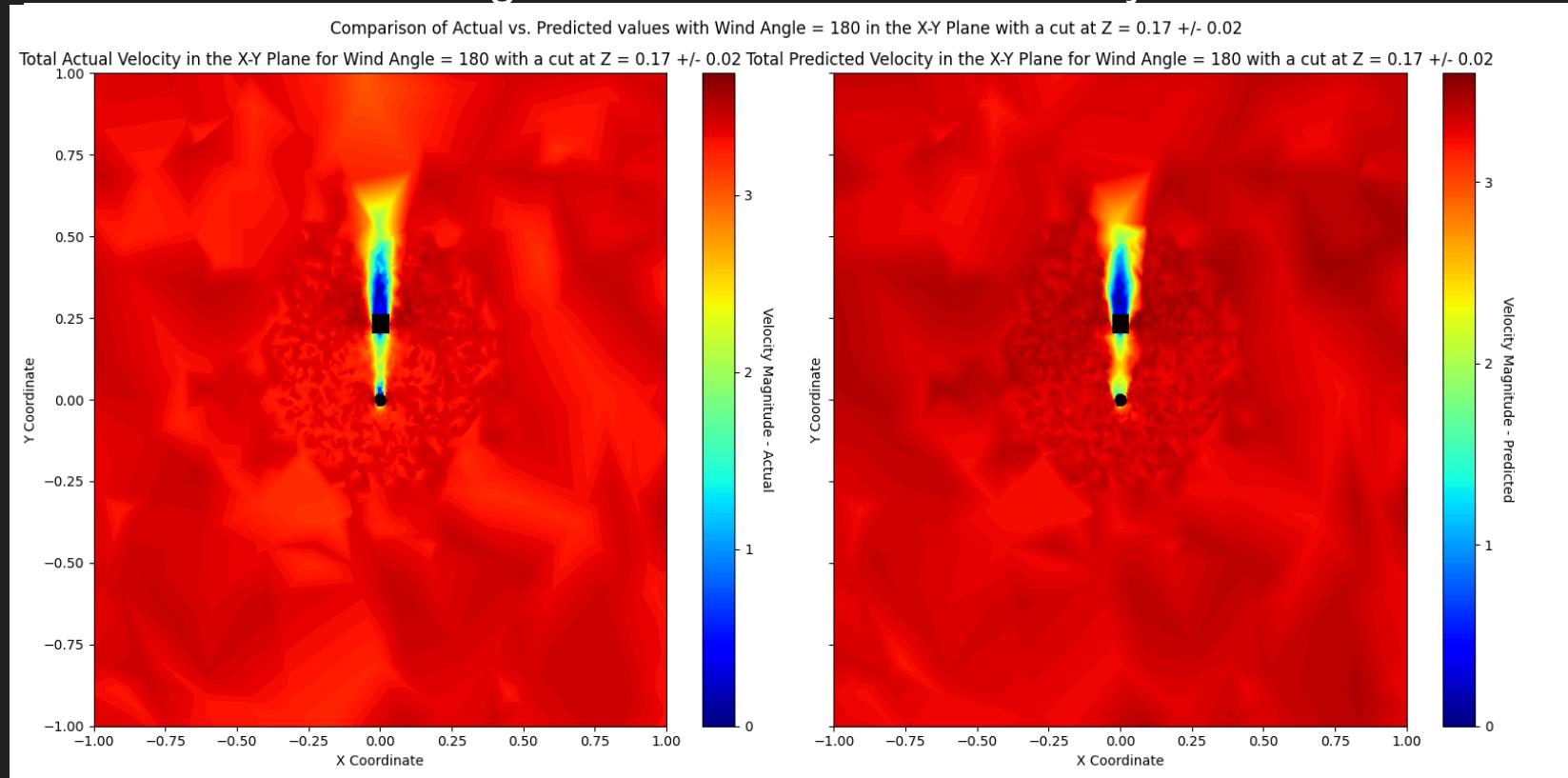
### Testing Results - X-Y Total Velocity Plot



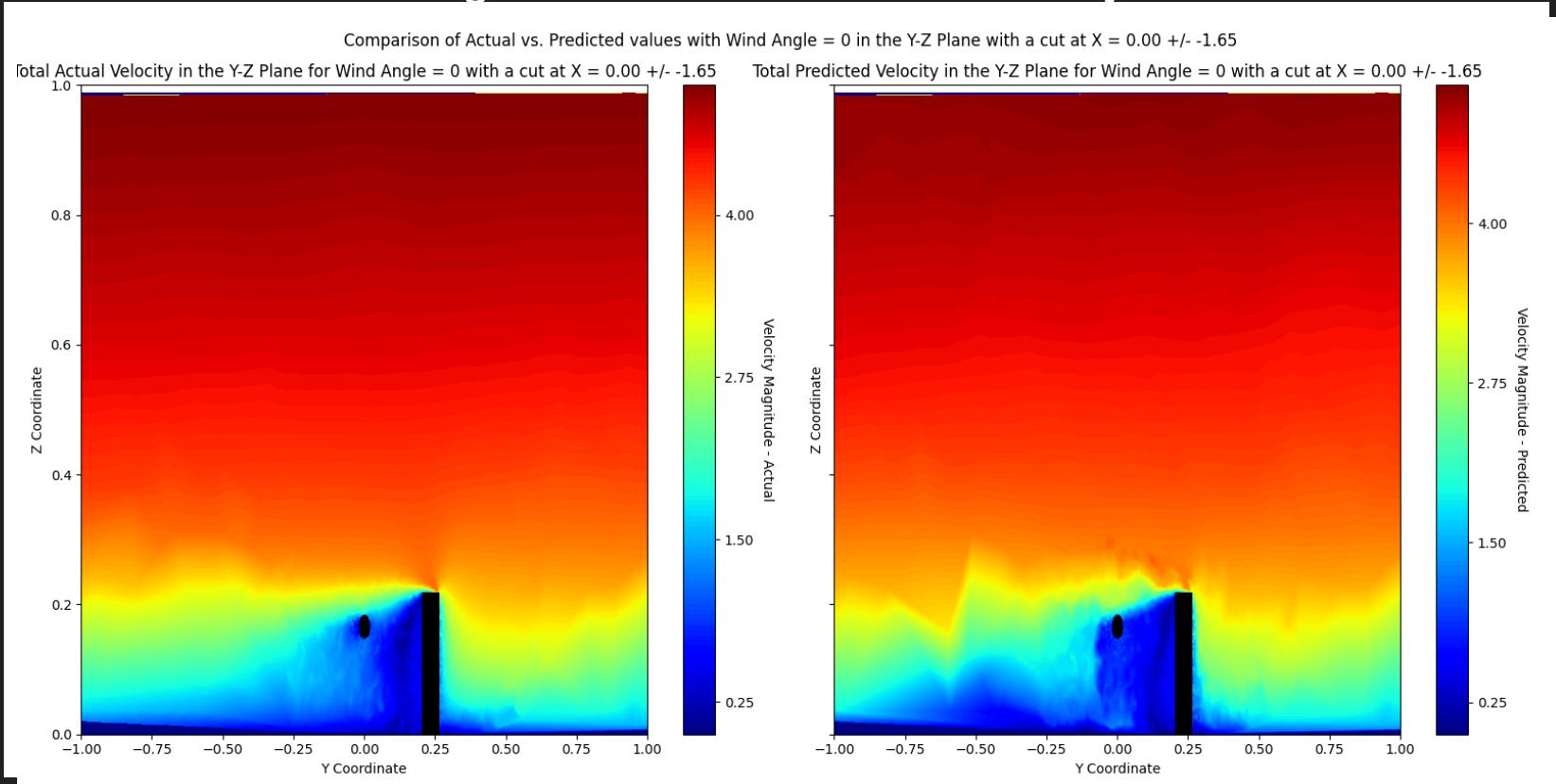
# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

### Testing Results - X-Y Total Velocity Plot



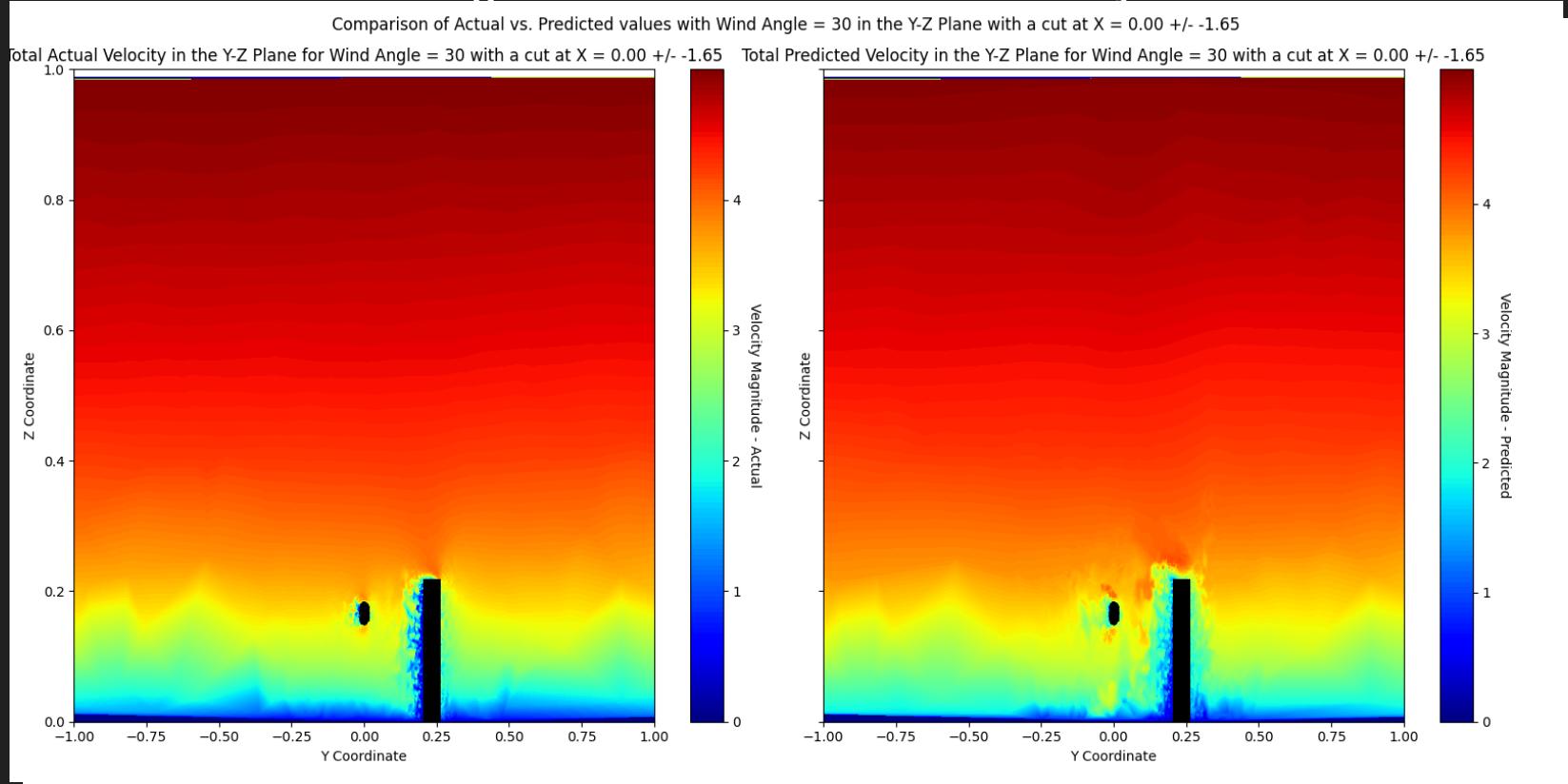
Progress so far - Data Loss + Cont Loss (Adam Optimizer)  
Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop  
Testing Results – Y-Z Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

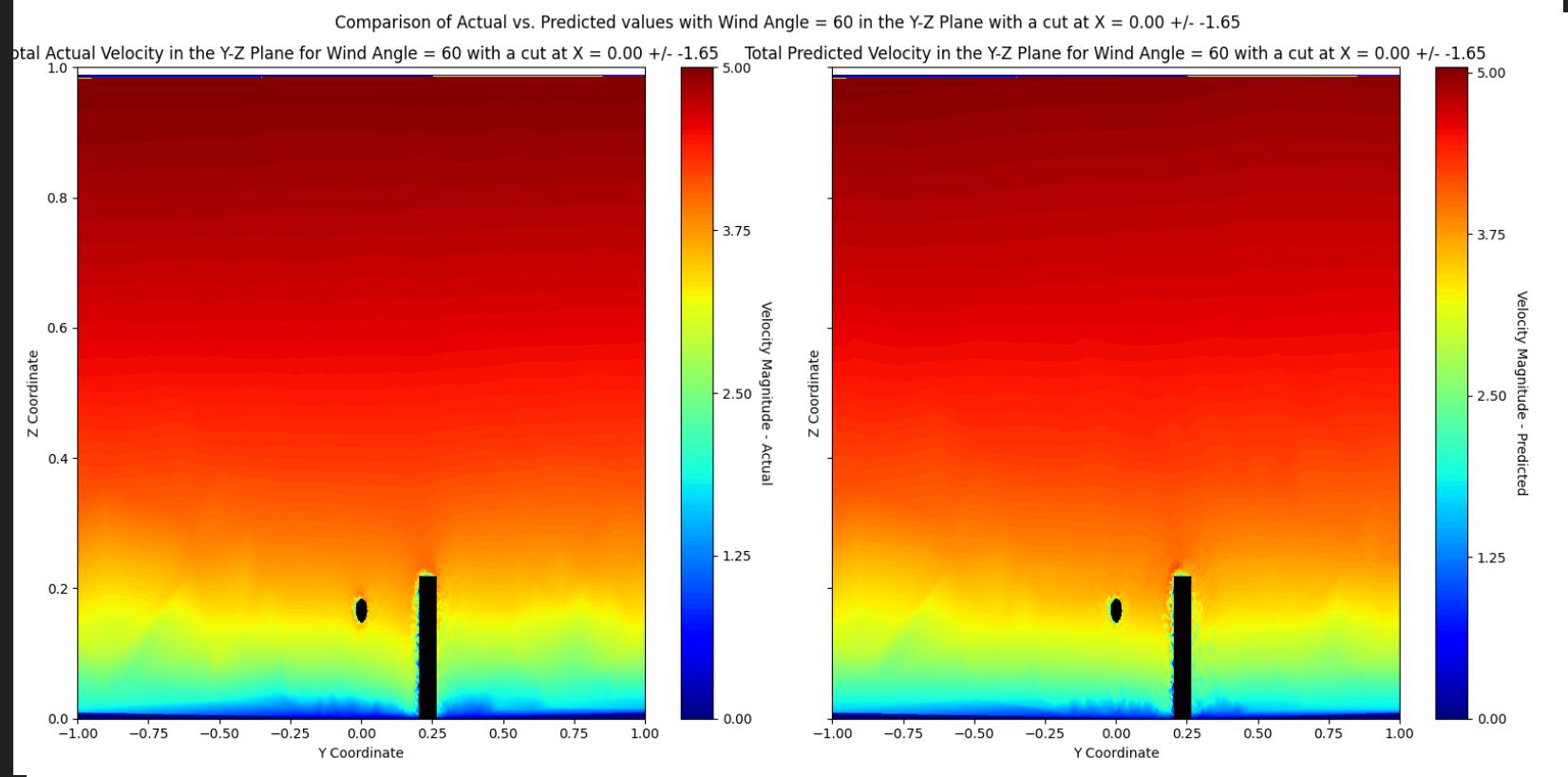
### Testing Results – Y-Z Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

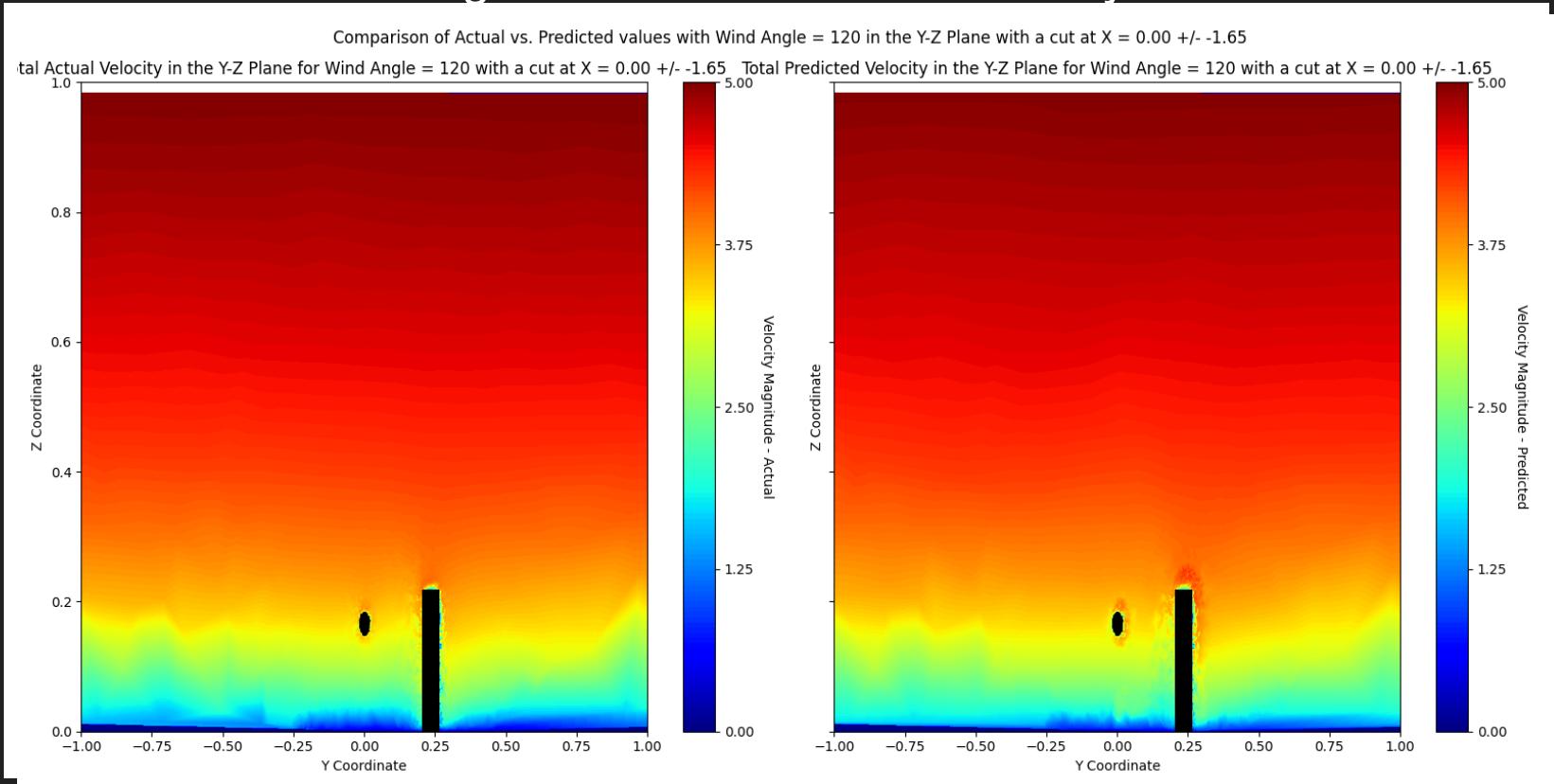
### Testing Results – Y-Z Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

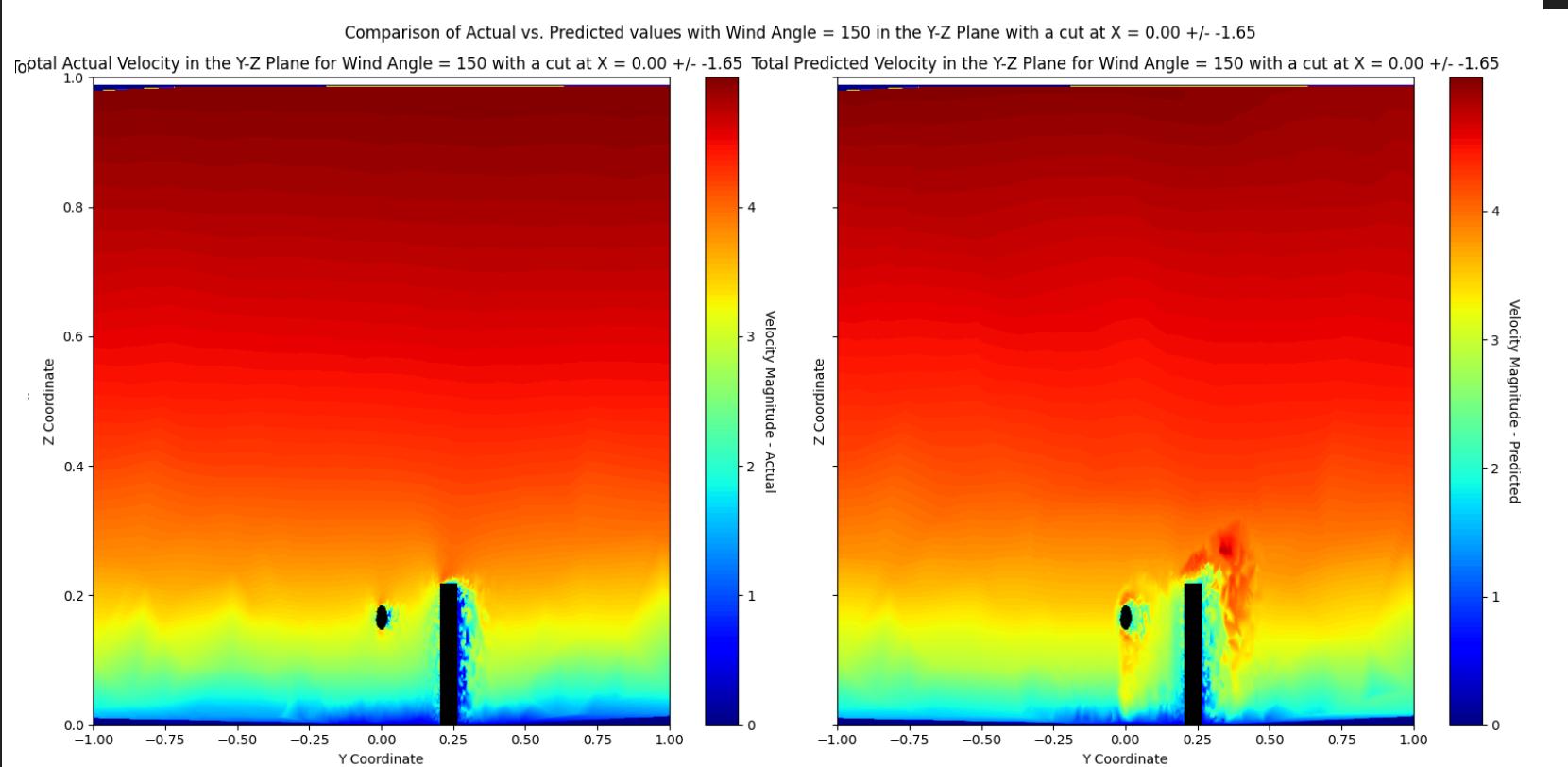
### Testing Results – Y-Z Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

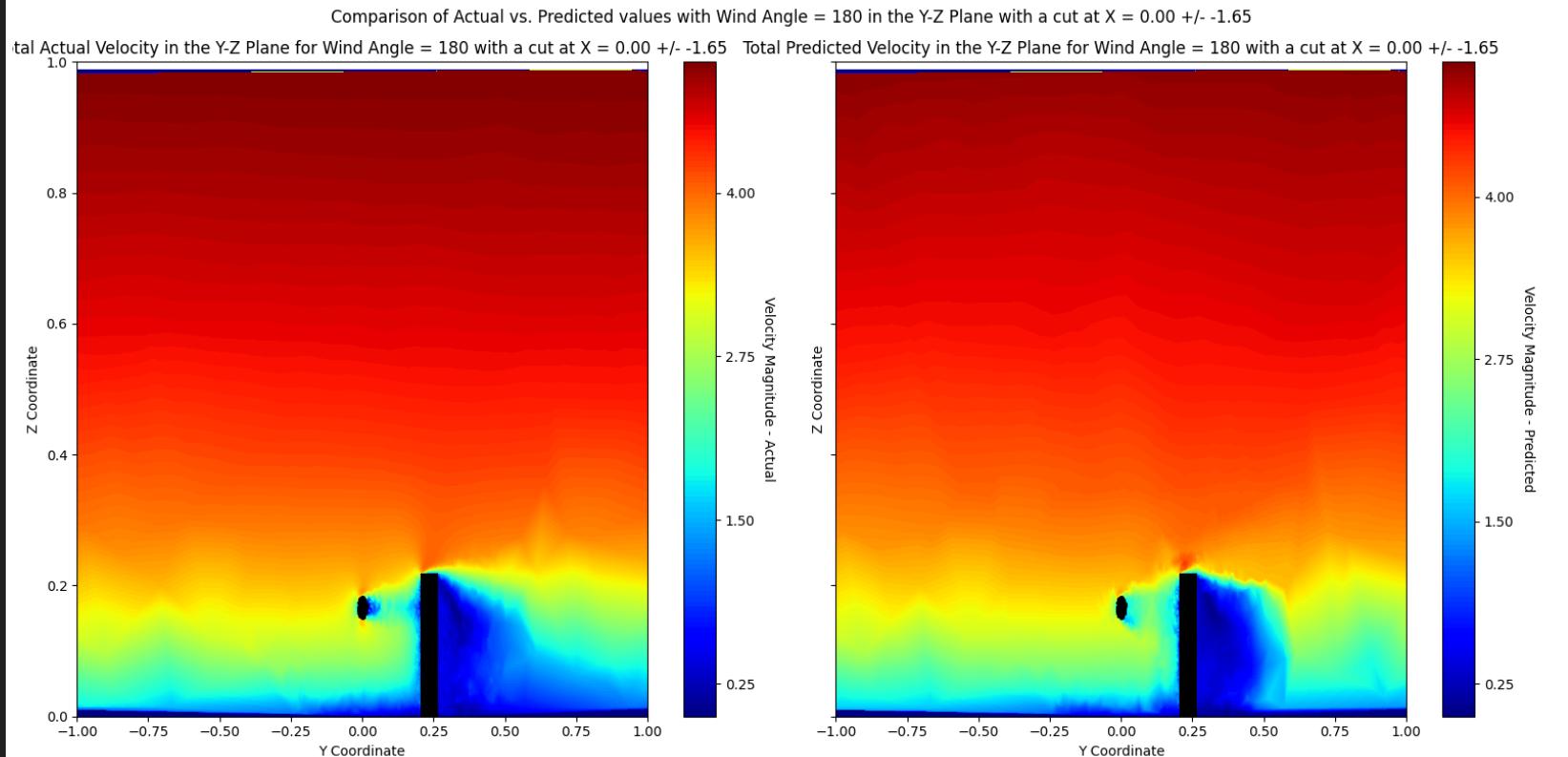
### Testing Results – Y-Z Total Velocity Plot



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

### Testing Results – Y-Z Total Velocity Plot



Progress so far - Data Loss + Cont Loss  
(Adam Optimizer)

Threshold = 1E-5 (9120 Epochs, so far...),  
GPU Laptop

Scripts v1 – PREDICTING (90,135 DEG)

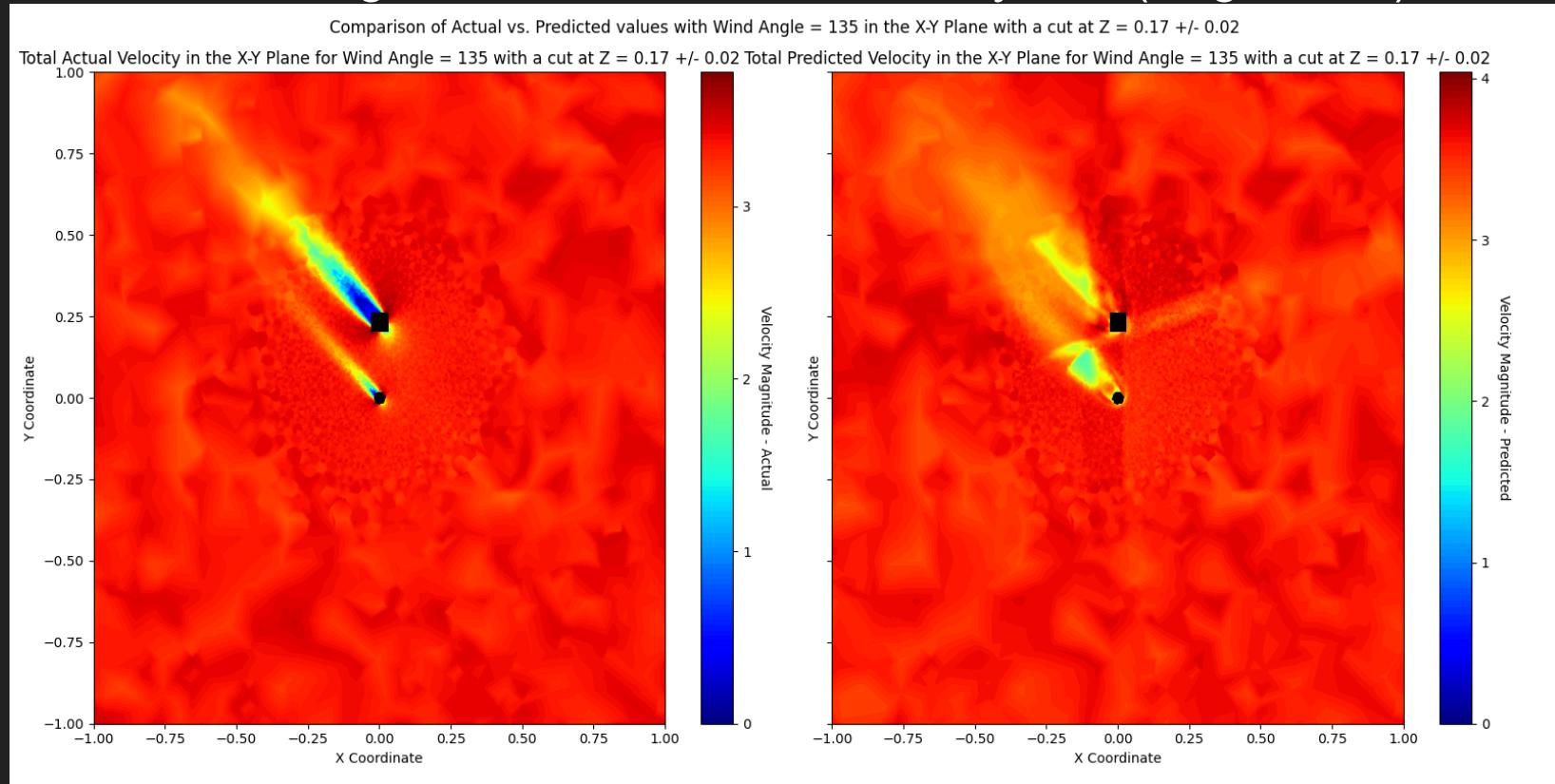
Progress so far - Data Loss + Cont Loss (Adam Optimizer)  
Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop  
Predicting Results – Metrics (Angle = 90)

Variable	MSE	RMSE	MAE	R2
Pressure	2.2540561	1.50135142	0.86987386	-0.2948265
Velocity:0	1.74568219	1.32124267	0.75204798	0.12026278
Velocity:1	4.33544267	2.08217258	1.99781828	-83.253256
Velocity:2	0.05317863	0.23060492	0.11664684	-0.6053989

# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

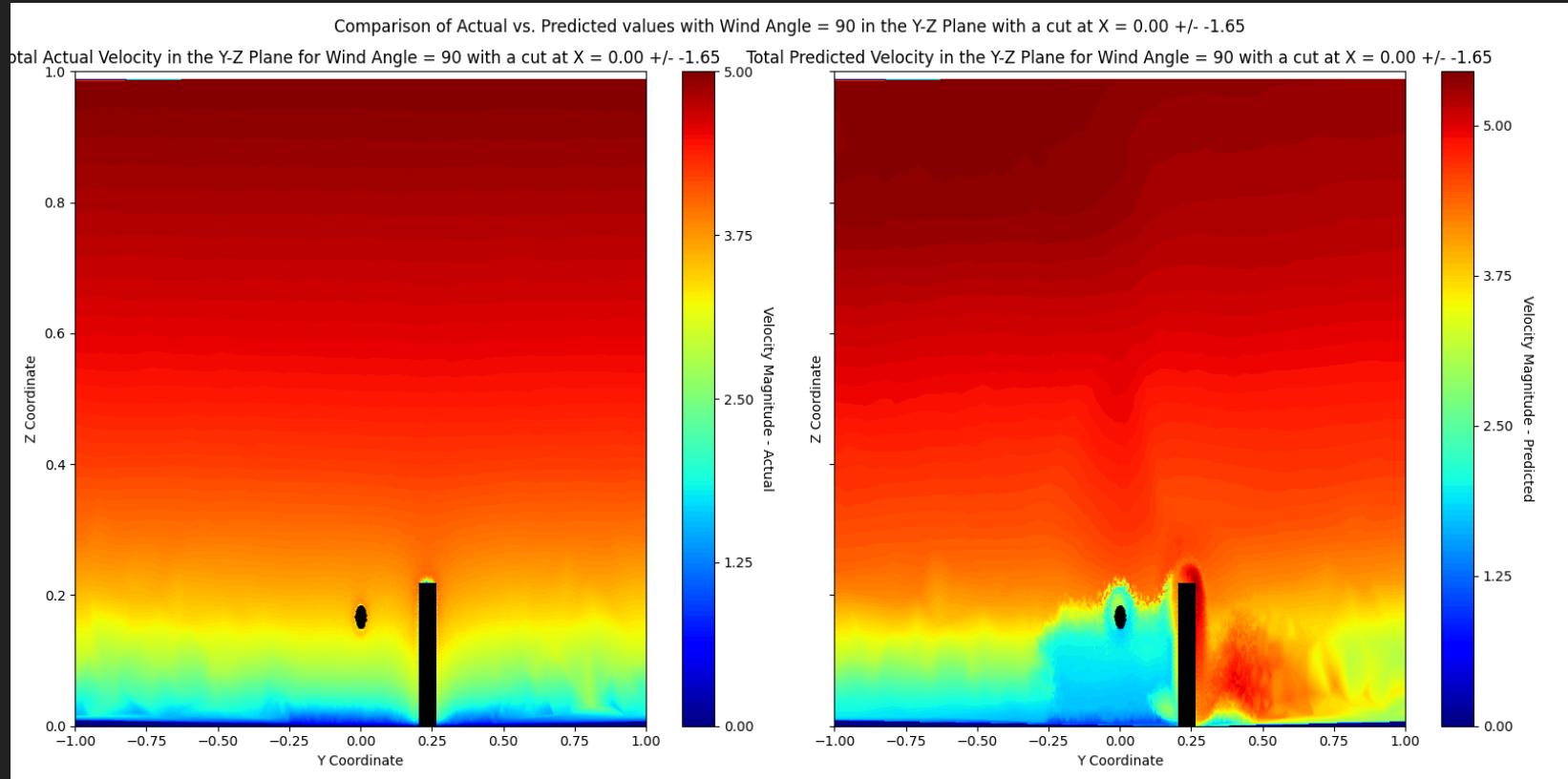
### Predicting Results - X-Y Total Velocity Plot (Angle = 90)



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

### Predicting Results - Y-Z Total Velocity Plot (Angle = 90)



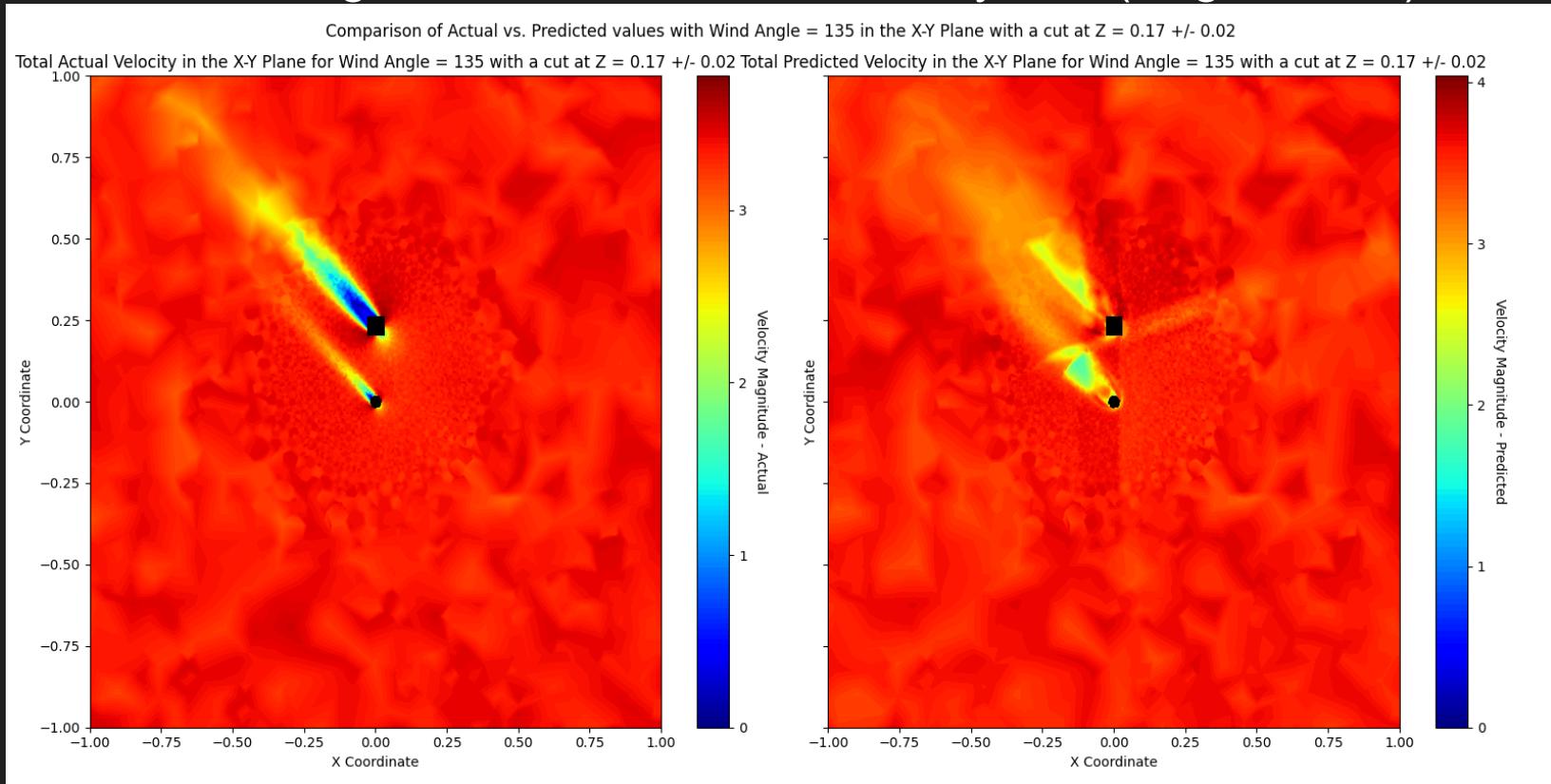
Progress so far - Data Loss + Cont Loss (Adam Optimizer)  
Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop  
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	1.48405698	1.21821877	0.68451799	0.12204593
Velocity:0	0.29097088	0.53941716	0.24768495	0.71451734
Velocity:1	0.37020207	0.60844233	0.46084663	0.64024342
Velocity:2	0.02470386	0.15717463	0.06013675	0.2448527

# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

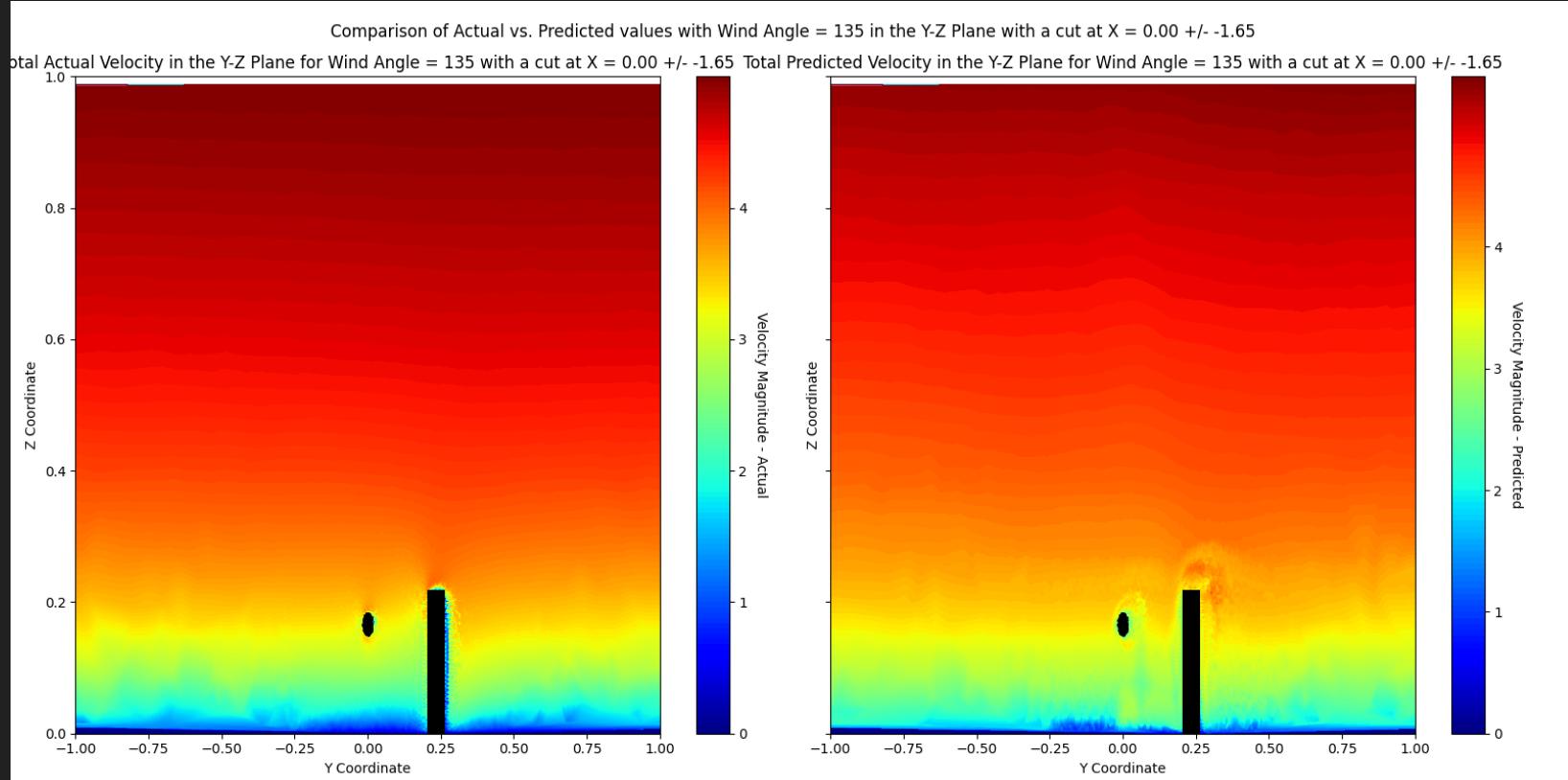
### Predicting Results - X-Y Total Velocity Plot (Angle = 135)



# Progress so far - Data Loss + Cont Loss (Adam Optimizer)

## Threshold = 1E-5 (9120 Epochs, so far...), GPU Laptop

### Predicting Results - Y-Z Total Velocity Plot (Angle = 135)



Progress so far - Data Loss + Cont Loss +  
RANS Loss (Adam Optimizer)

Threshold = 1E-5 (5400 Epochs, so far...),  
GPU Workstation

Scripts v1 - TESTING

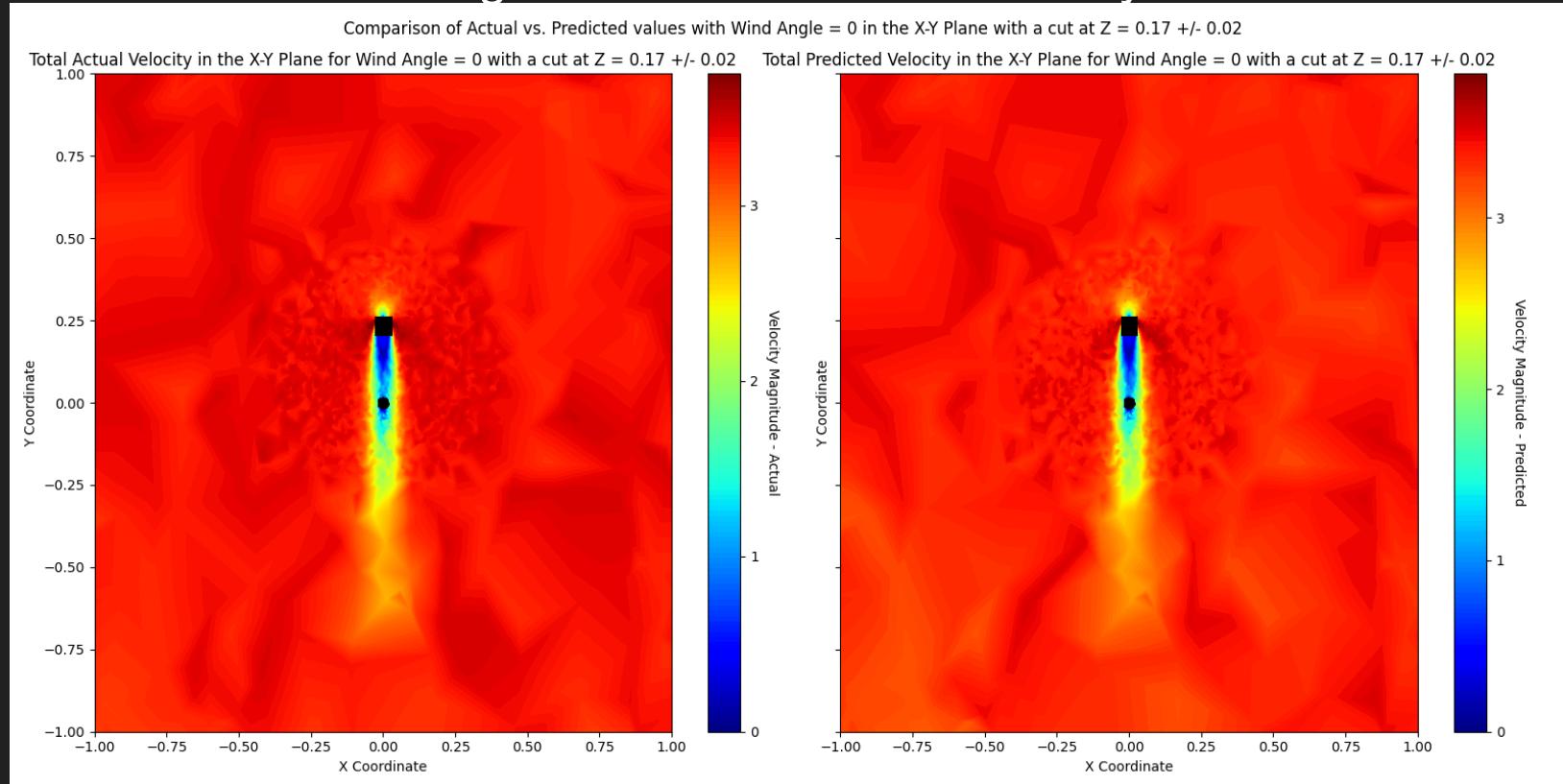
Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)  
Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation  
Testing Results - Metrics

Variable	MSE	RMSE	MAE	R2
Pressure	0.00364972	0.06041294	0.03737356	0.99922606
Velocity:0	0.00168196	0.04101172	0.02408311	0.99916676
Velocity:1	0.00385195	0.06206411	0.03741128	0.9995341
Velocity:2	0.00012084	0.01099263	0.00596333	0.99609346

# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

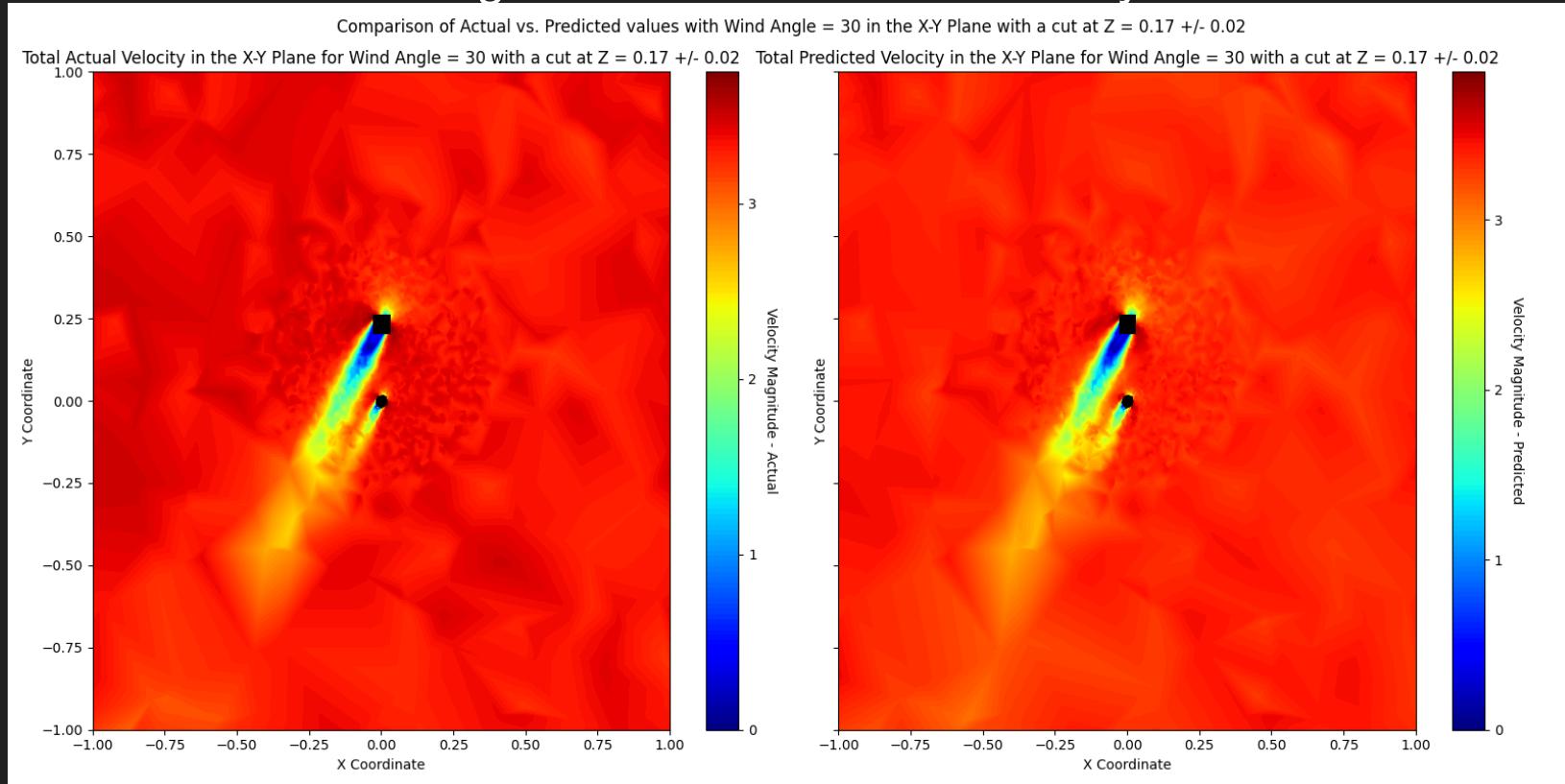
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

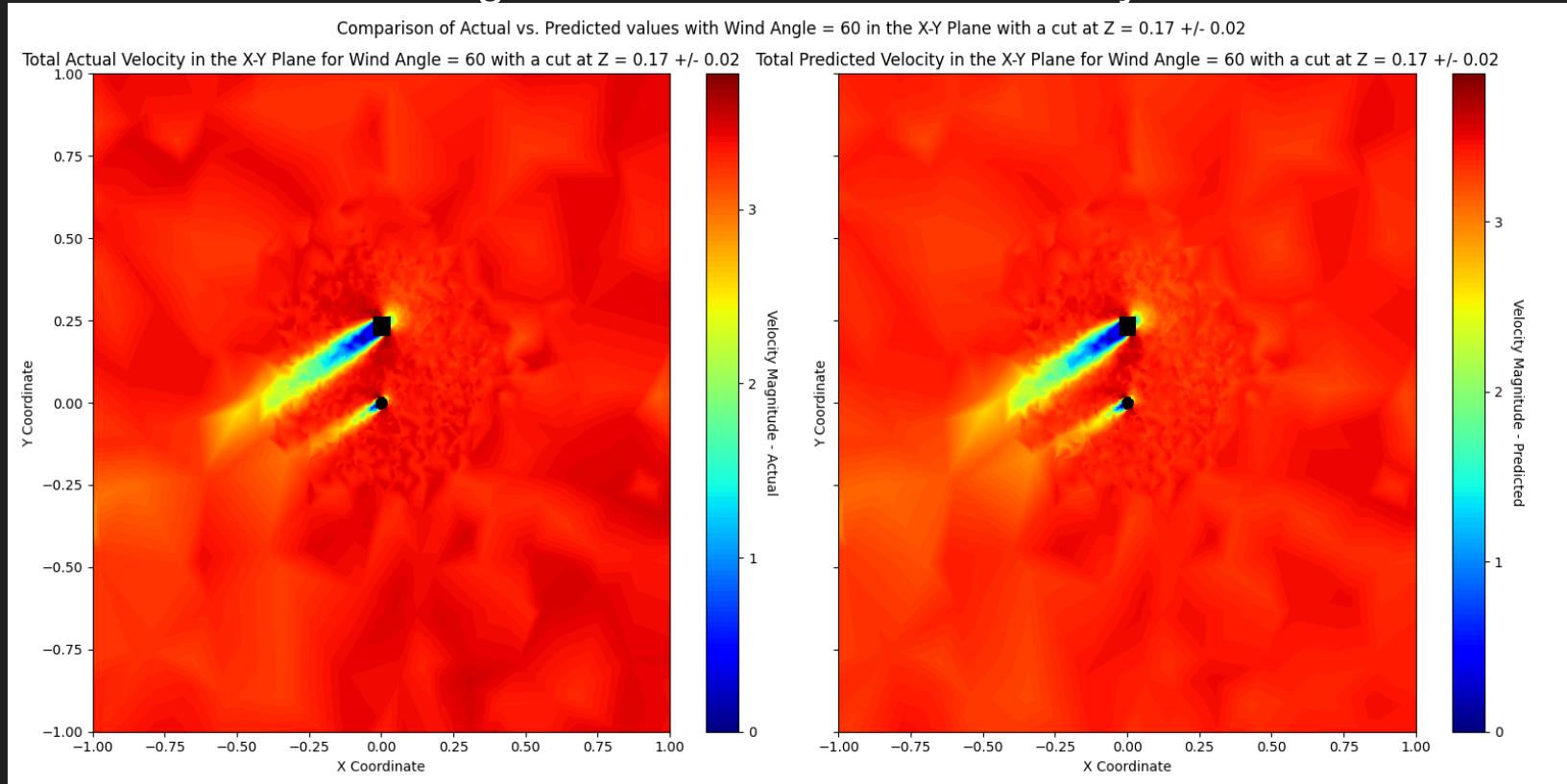
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

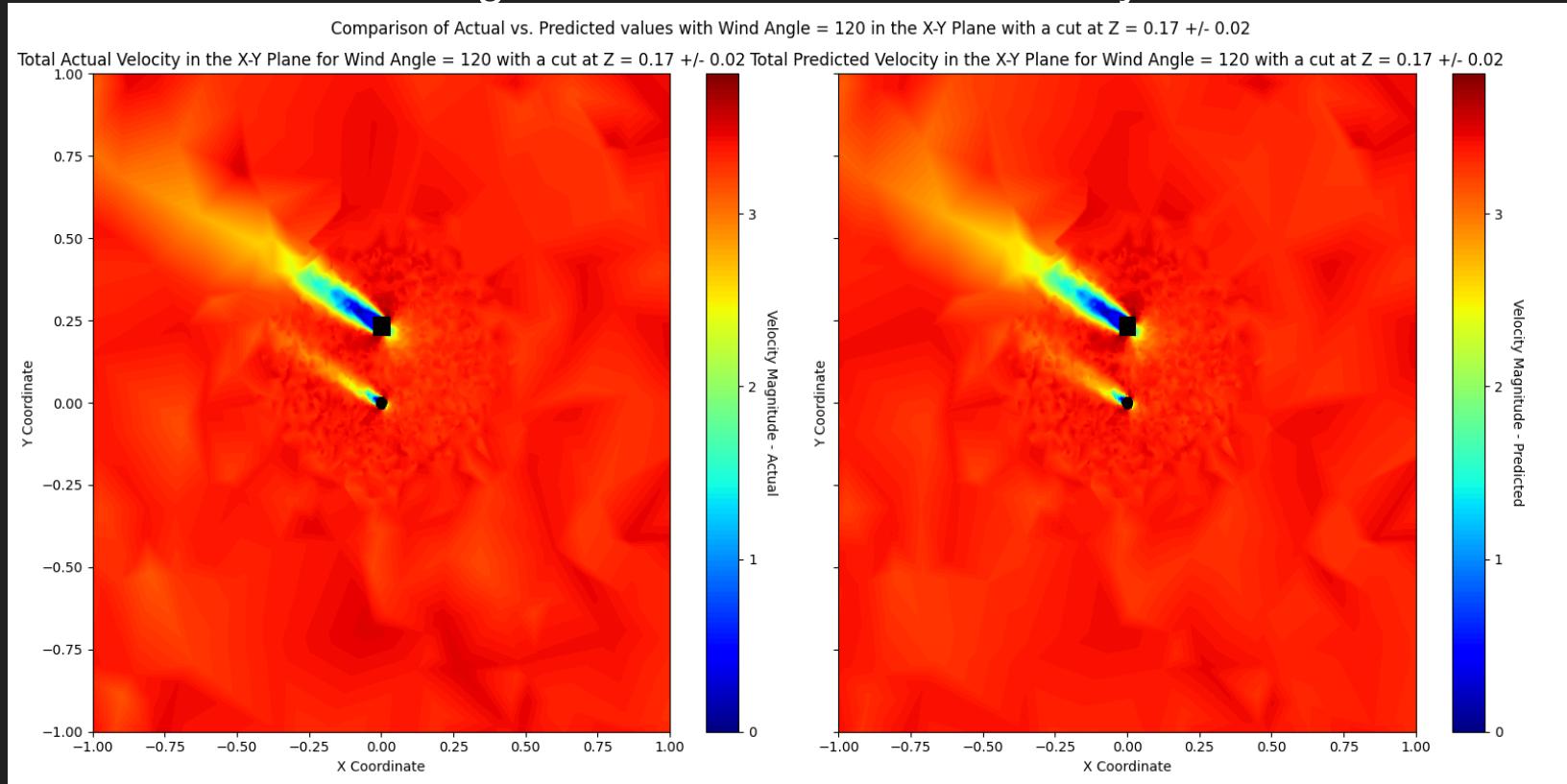
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

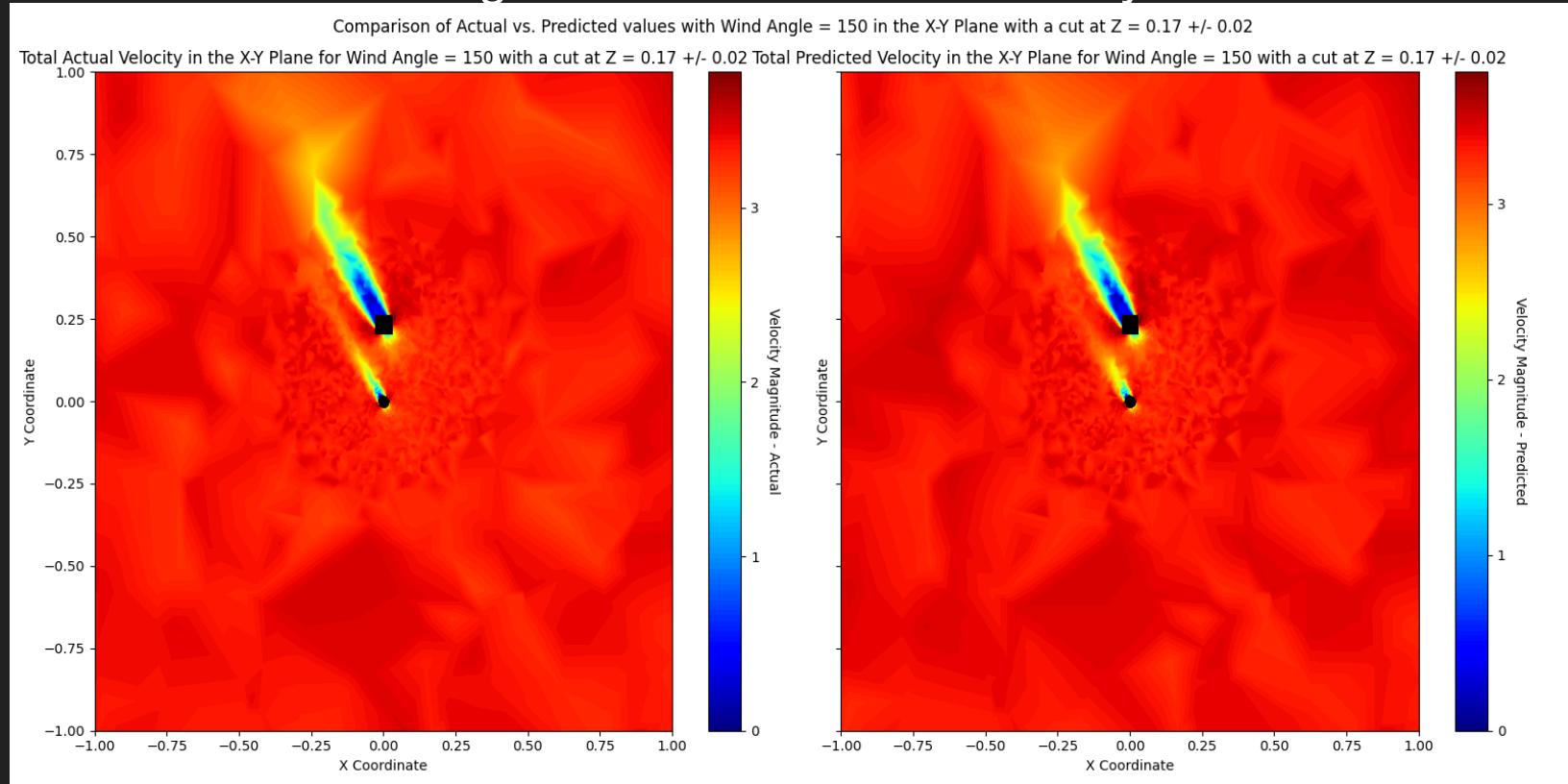
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

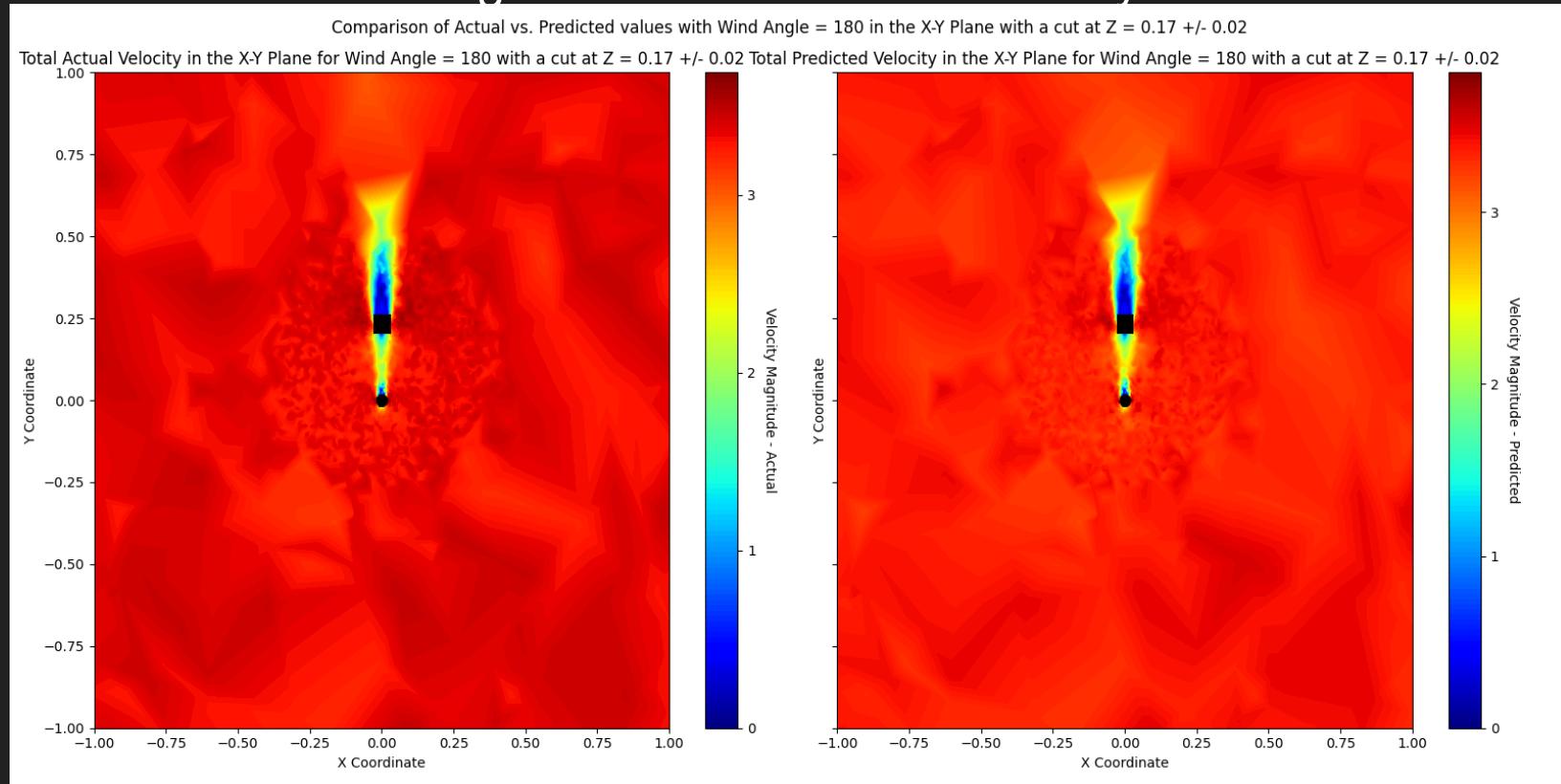
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

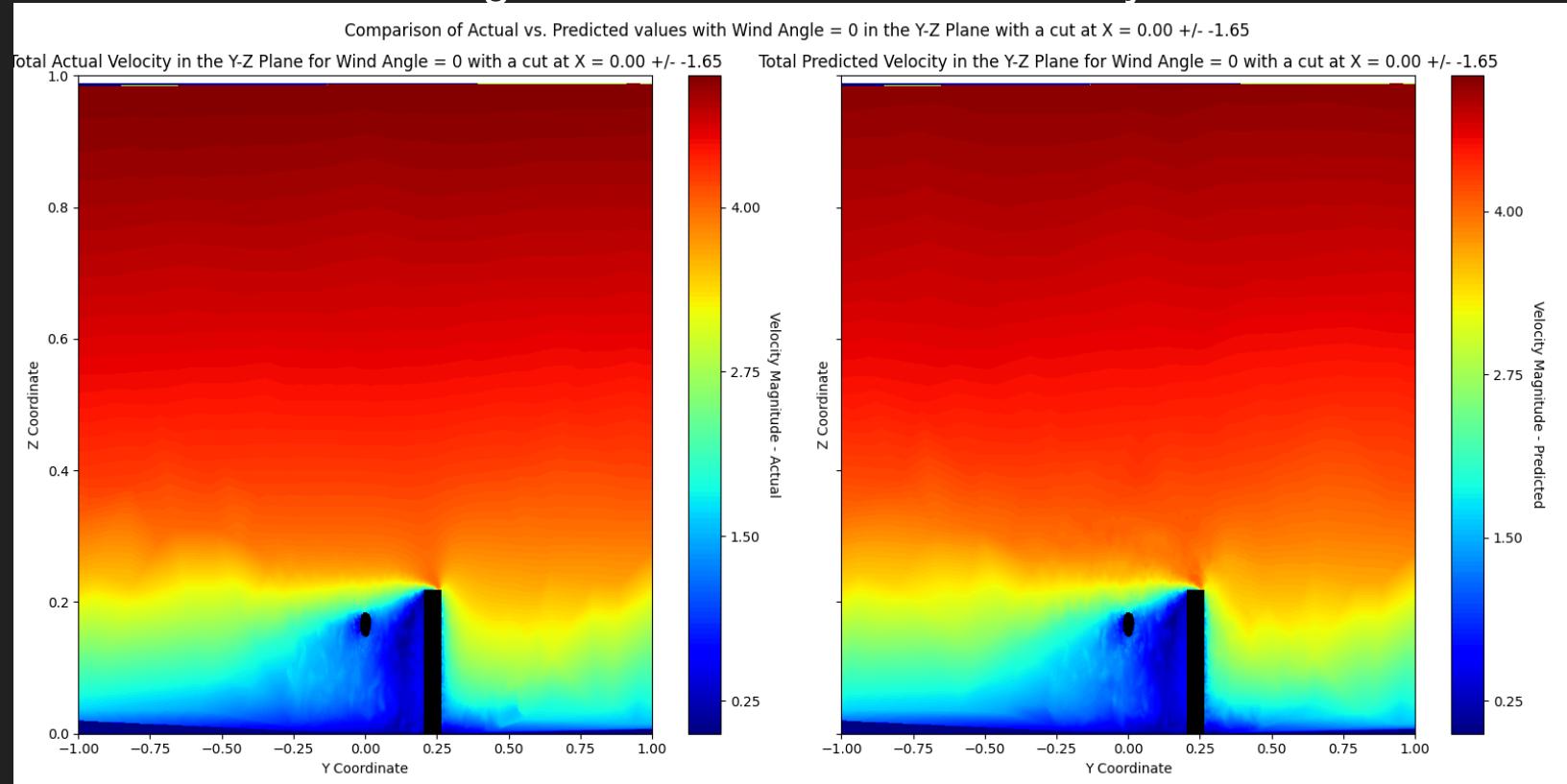
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

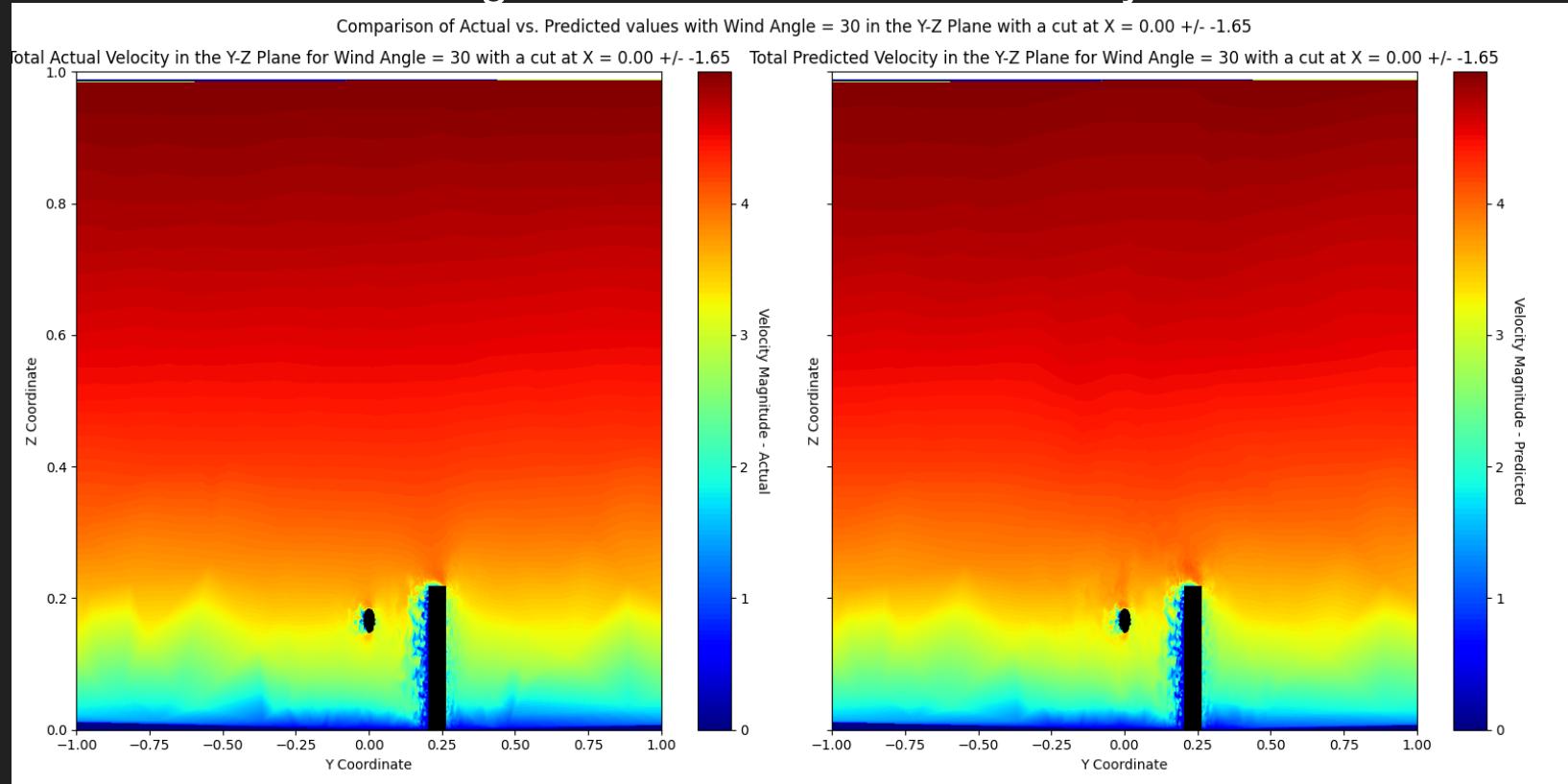
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

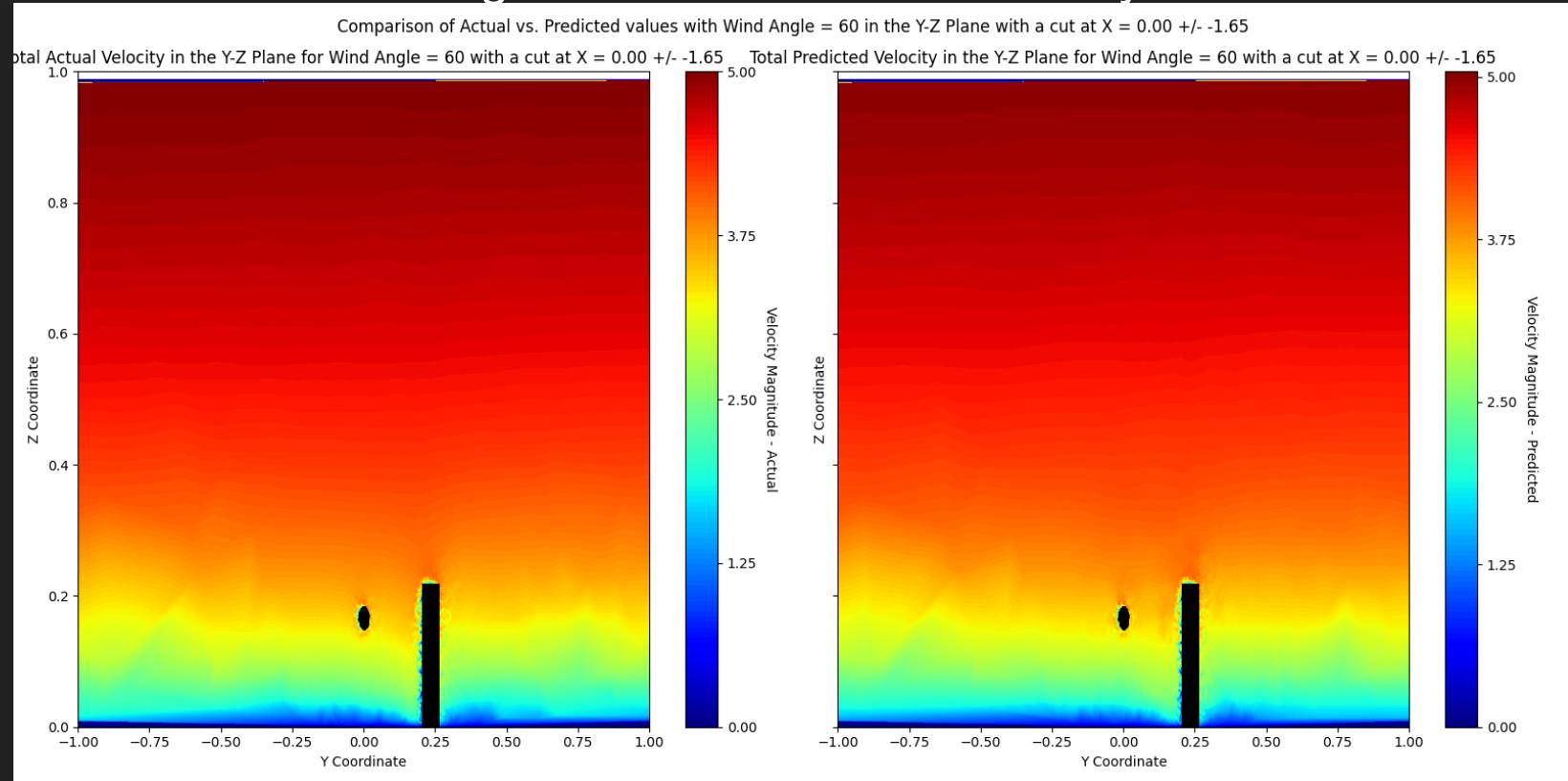
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

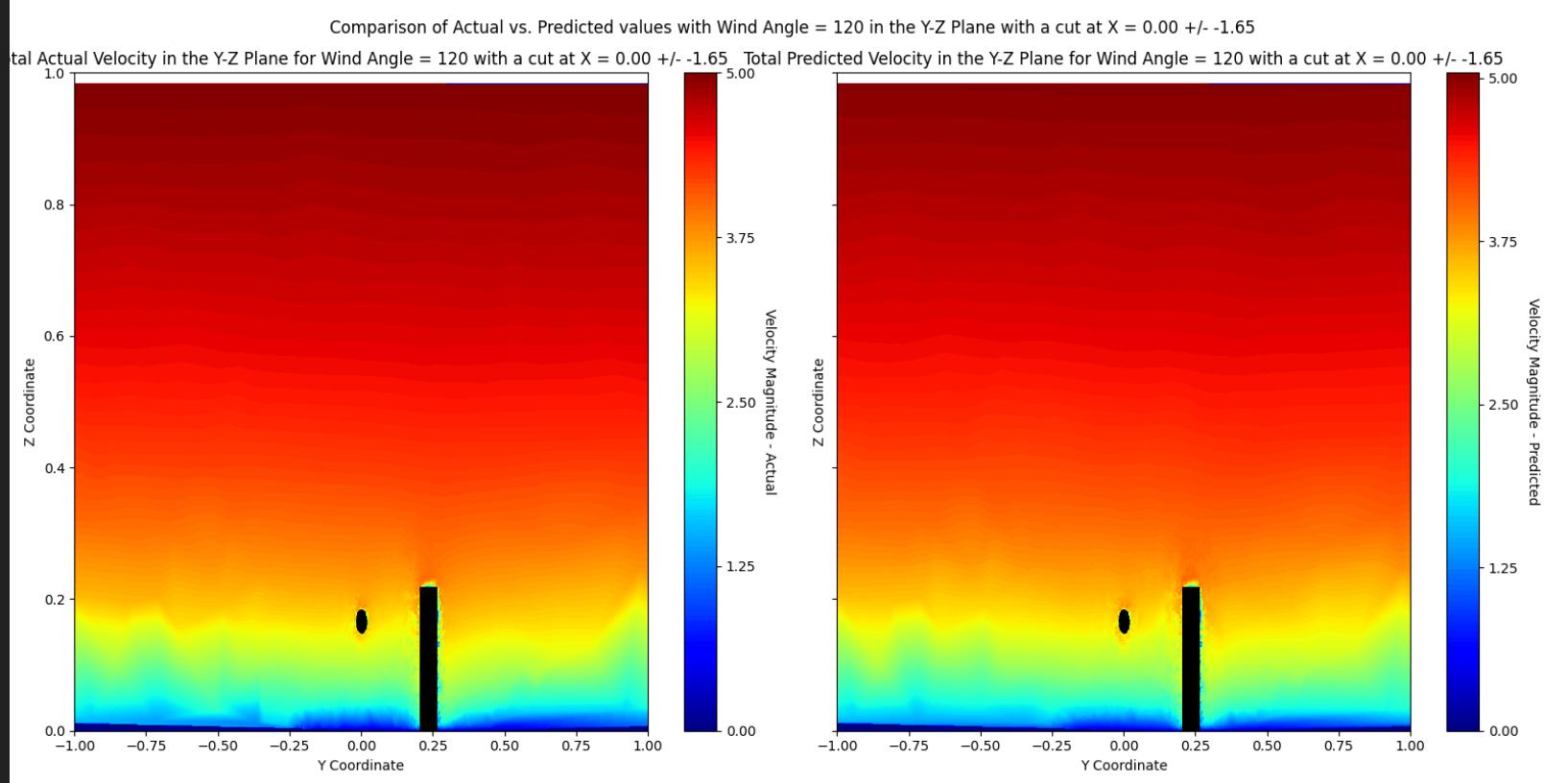
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

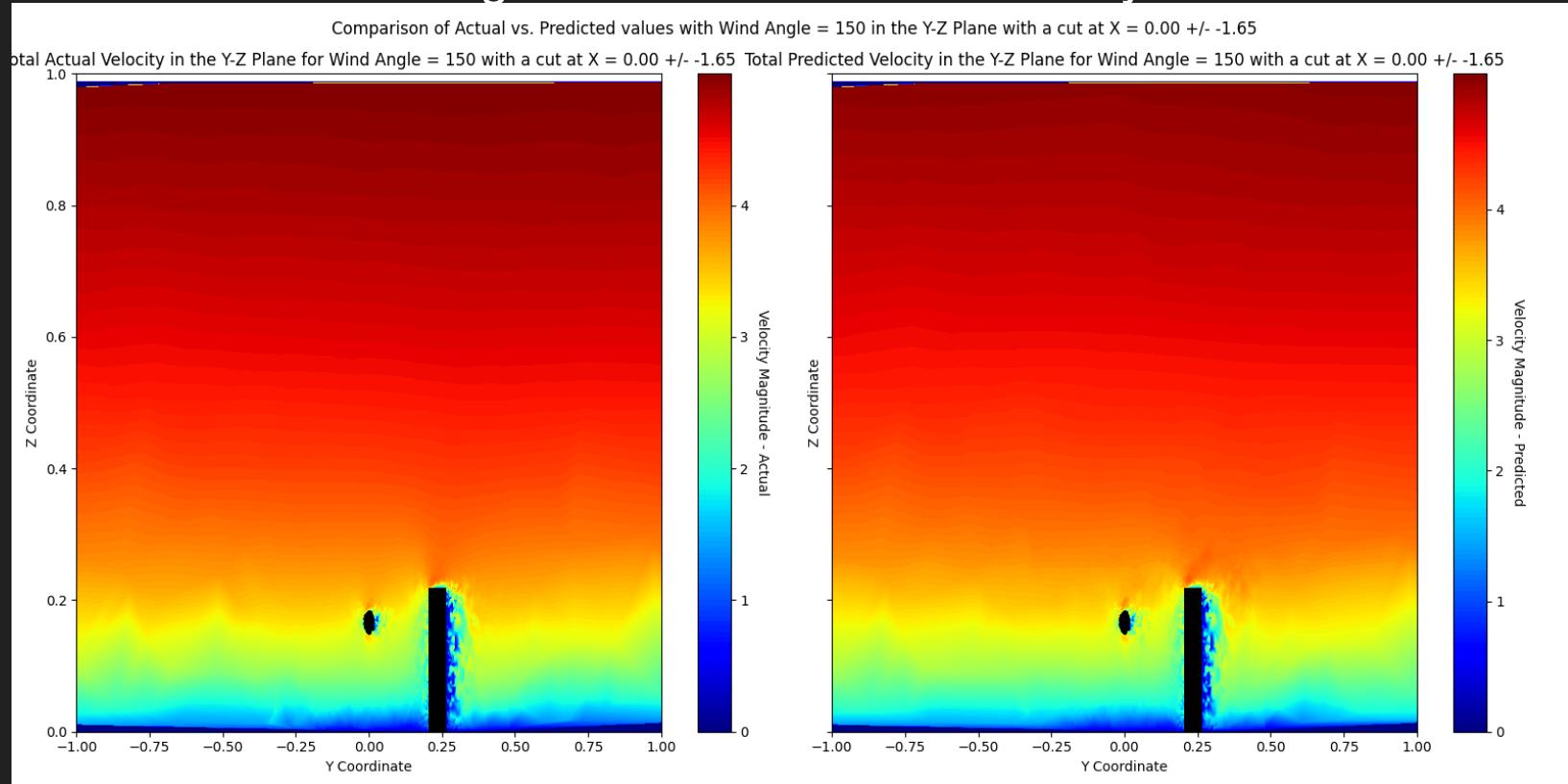
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

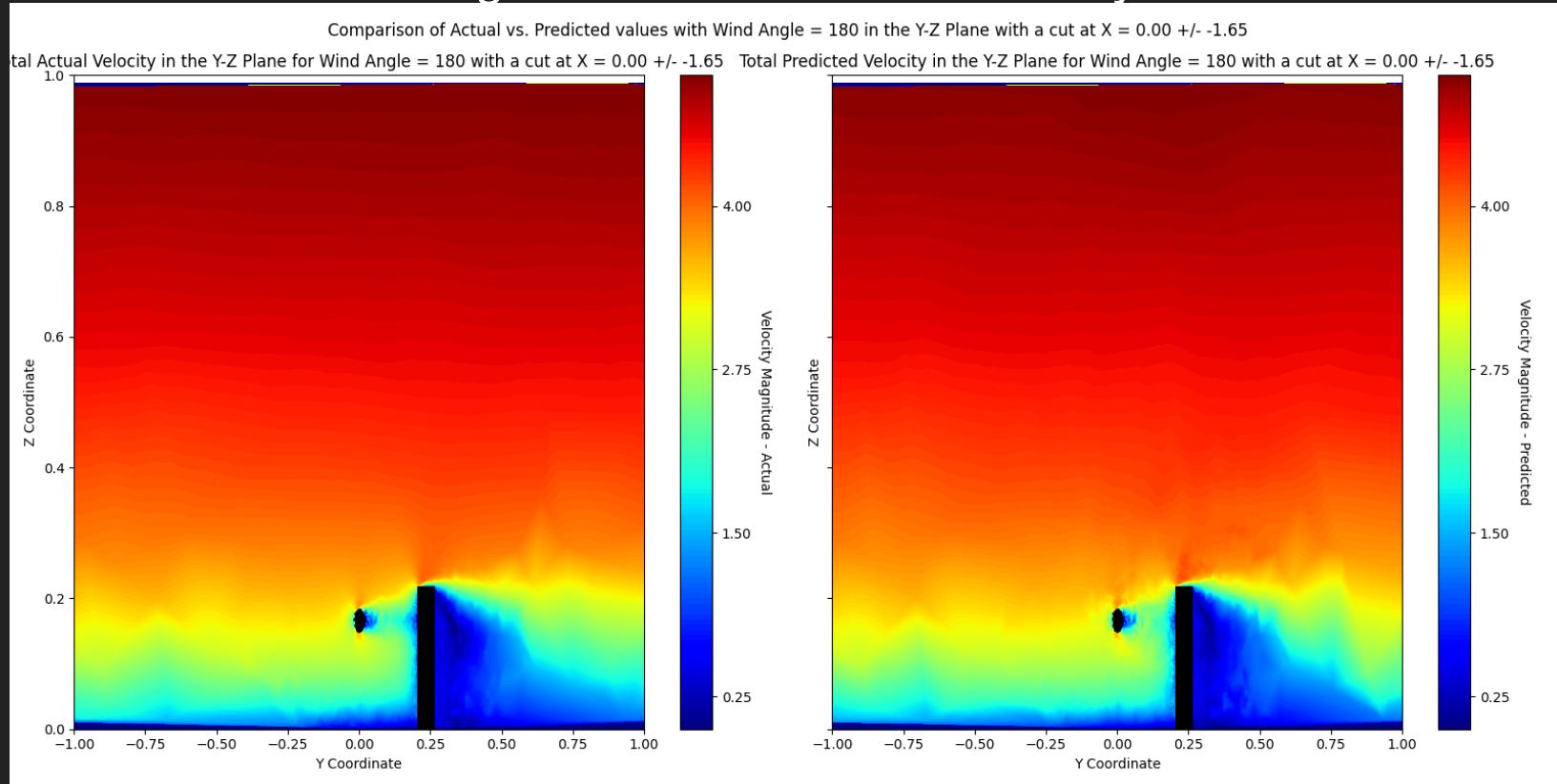
### Testing Results - X-Y Total Velocity Plot



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

### Testing Results - X-Y Total Velocity Plot



Progress so far - Data Loss + Cont Loss +  
RANS Loss (Adam Optimizer)

Threshold = 1E-5 (5400 Epochs, so far...),  
GPU Workstation

Scripts v1 – PREDICTING (90,135 DEG)

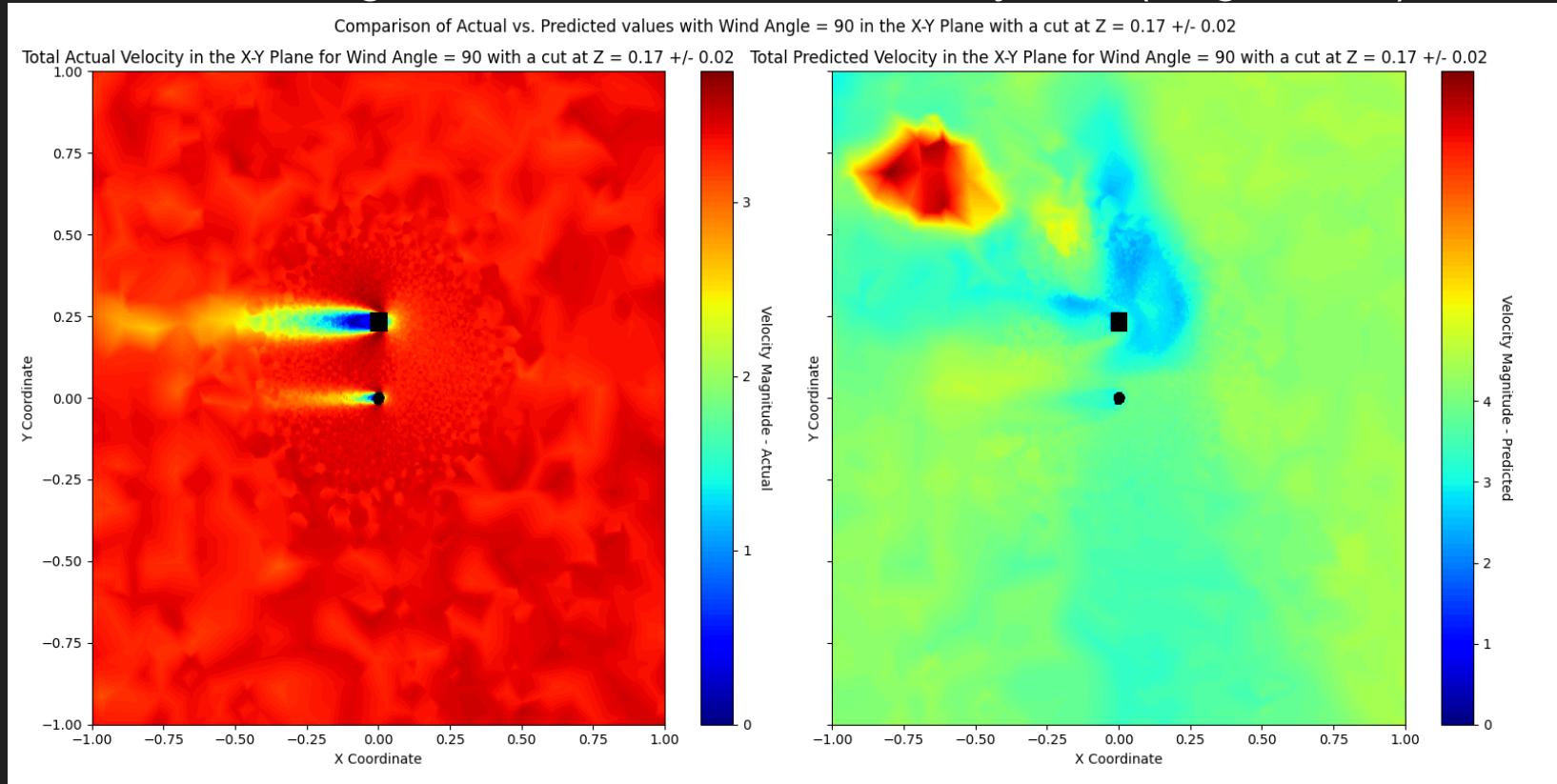
Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)  
Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation  
Predicting Results – Metrics (Angle = 90)

Variable	MSE	RMSE	MAE	R2
Pressure	29.8978071	5.46788872	3.85787731	-16.174583
Velocity:0	1.02771039	1.01376052	0.90530051	0.48208495
Velocity:1	0.61835036	0.78635257	0.5696696	-11.016773
Velocity:2	0.7911997	0.88949407	0.45162508	-22.885368

# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

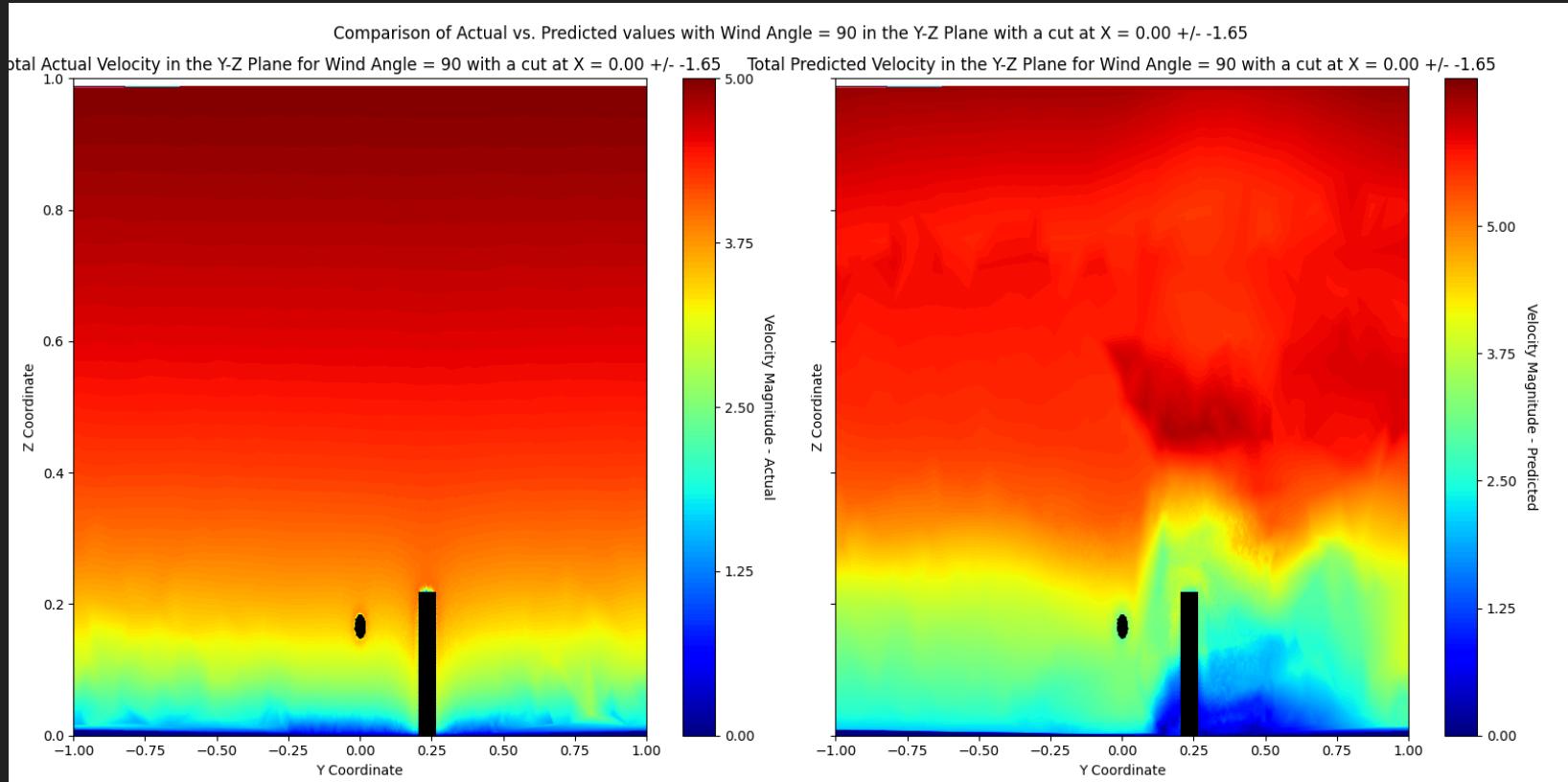
### Predicting Results - X-Y Total Velocity Plot (Angle = 90)



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

### Predicting Results - Y-Z Total Velocity Plot (Angle = 90)



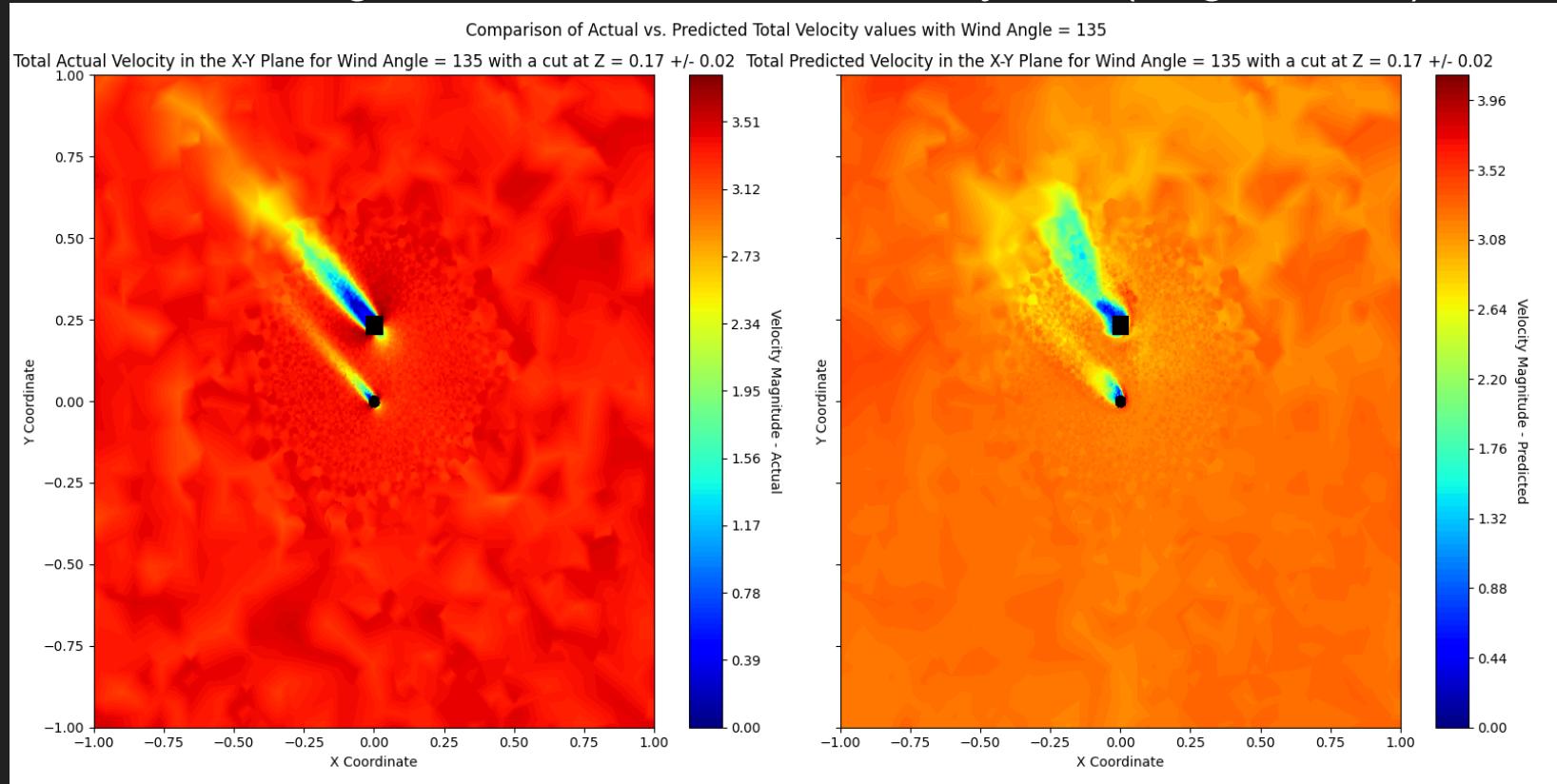
Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)  
Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation  
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	1.55444569	1.24677411	0.58380363	0.08040464
Velocity:0	0.28687284	0.53560512	0.38439829	0.71853807
Velocity:1	0.2985522	0.5463993	0.3817838	0.70987164
Velocity:2	0.02667502	0.16332491	0.06180706	0.1845983

# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

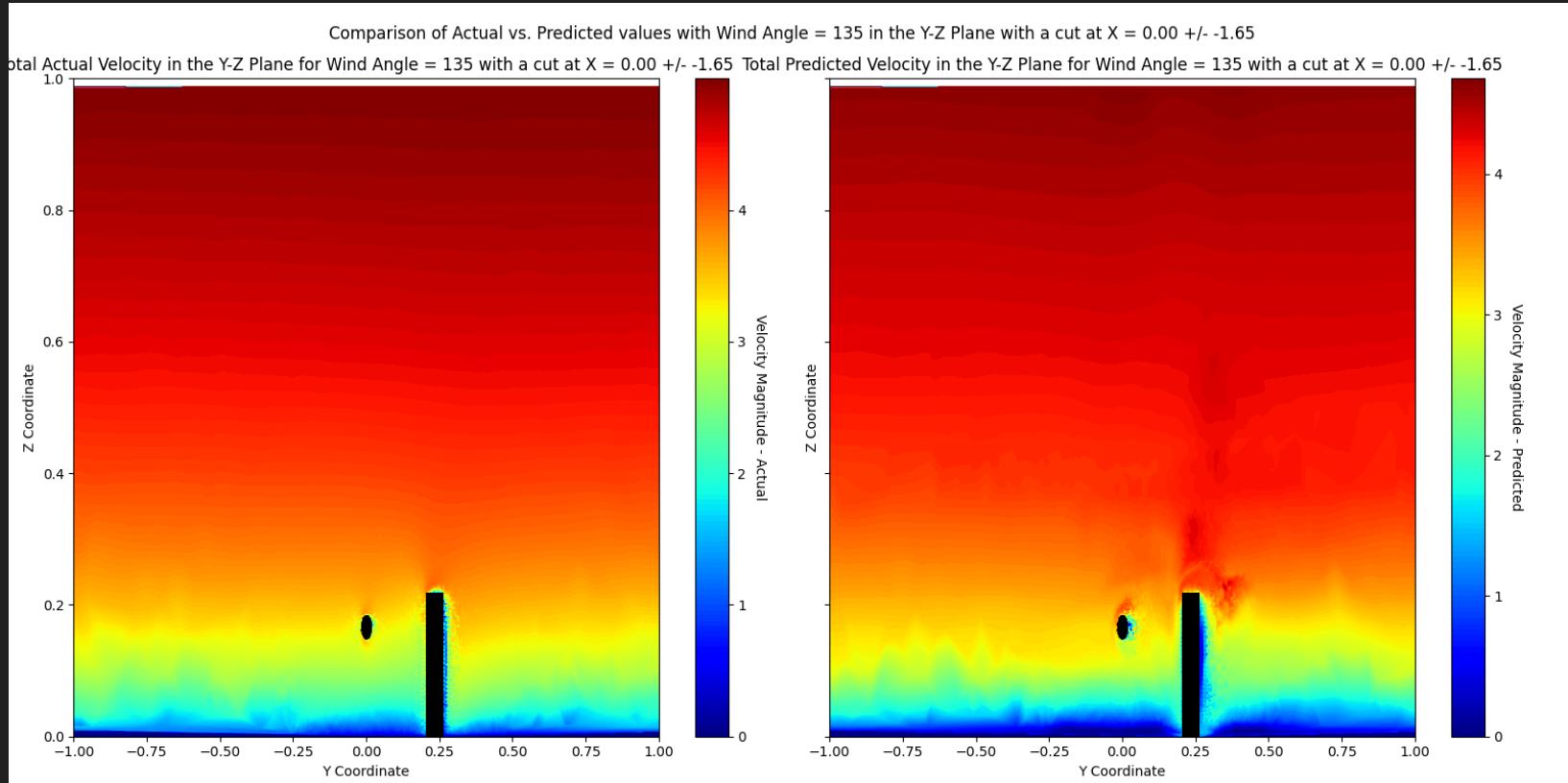
### Predicting Results - X-Y Total Velocity Plot (Angle = 135)



# Progress so far - Data Loss + Cont Loss + RANS Loss (Adam Optimizer)

## Threshold = 1E-5 (5400 Epochs, so far...), GPU Workstation

### Predicting Results - Y-Z Total Velocity Plot (Angle = 135)



# Scripts v2 – Preliminary Results

Progress so far - Data Loss Only  
Min-Max Scalar  
(Adam Optimizer)

Threshold = 1E-5 (18390 Epochs, so far...),  
GPU Laptop

Scripts v2 – PREDICTING (135 DEG)

# Some Parameters

Infinite epochs - instead the criteria for stopping is  $\text{loss}_{\{n\}} - \text{loss}_{\{n-1\}} < \epsilon$  for 10 consecutive epochs where  $n$  is the epoch number and  $\epsilon = 1E-5$  (user defined)

We have the data for 8 angles, [0, 30, 60, 90, 120, 135, 150, 180] in degrees

We concatenate the data for angles = [0, 30, 60, 90, 120, 150, 180] and then take 99.99% of the dataset with random seed = 42 for training and 0.01% for testing

By using the whole dataset we hope to make the NN learn about wind angle such that the parameters become functions of the wind angle

Then using the trained neural network we predict the data for angle = 135

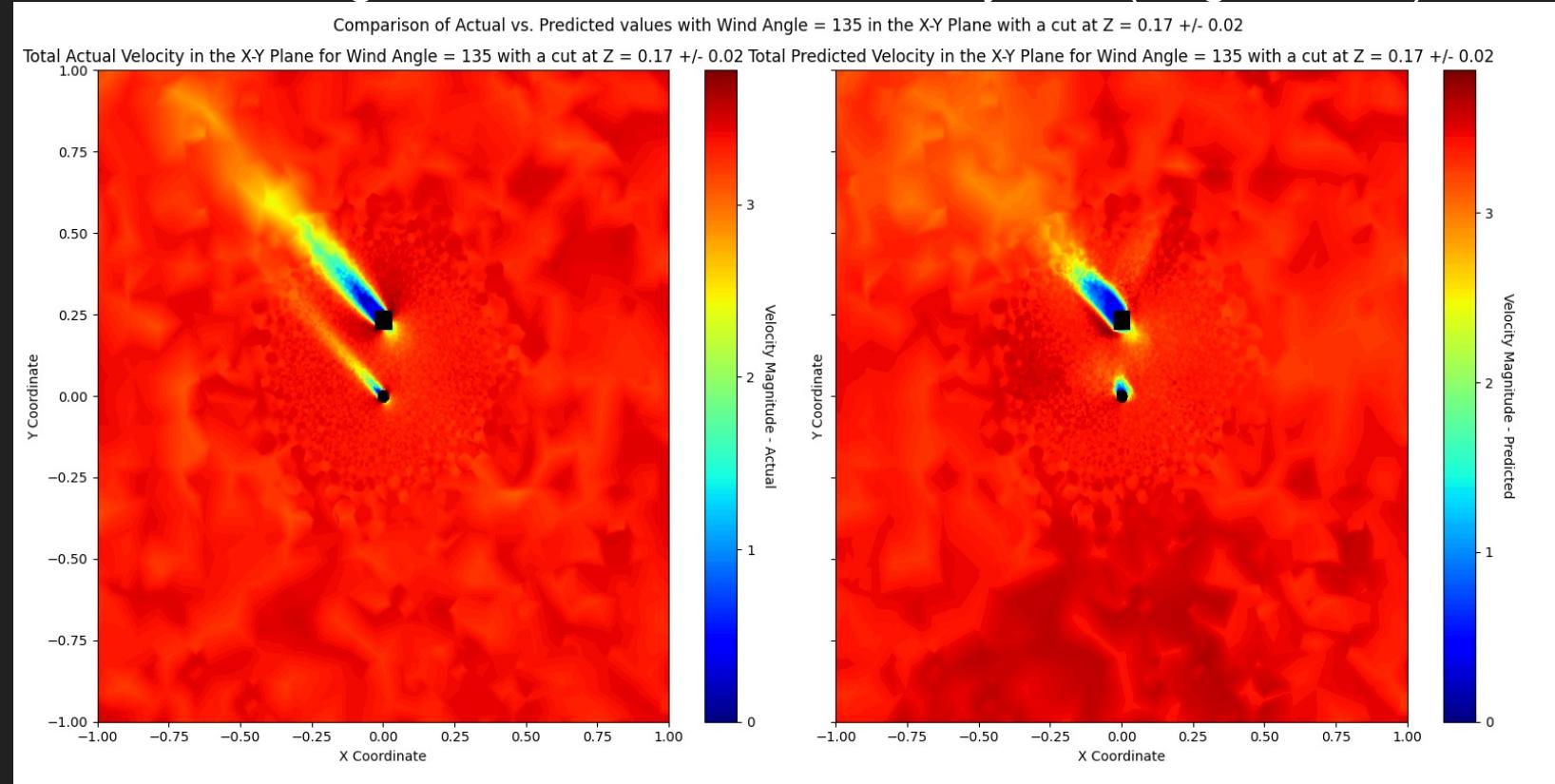
Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar)  
Threshold = 1E-5 (18390 Epochs, so far...), GPU Laptop  
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	1.00526432	1.0026287	0.45143973	0.40529656
Velocity:0	0.09865773	0.31409828	0.17352223	0.9032034
Velocity:1	0.09385991	0.30636565	0.19613531	0.90878867
Velocity:2	0.03783228	0.19450521	0.08062557	-0.1564531

# Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar)

## Threshold = 1E-5 (18390 Epochs, so far...), GPU Laptop

### Predicting Results - X-Y Total Velocity Plot (Angle = 135)



# Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar) Threshold = 1E-5 (18390 Epochs, so far...), GPU Laptop Predicting Results - Y-Z Total Velocity Plot (Angle = 135)

